EFFECT OF NARRATIVE STRUCTURES ON SENSEMAKING

A Thesis

by

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ABSTRACT

Making sense of a given situation involves an active processing of information to achieve understanding. Such situations involve a common activity of analyzing a body of the given or derived data. Prior literature shows that during sensemaking process, individuals search for knowledge representation and encoding data in that representation to answer task specific questions.

In this research we are interested to find implications of 'narrative structure' used as a mental model during knowledge representation phase of sense making process as proposed in 'Pirolli & Card's sensemaking model and to examine how this mental models affects overall quality of the synthesized knowledge derived during given analysis task.

We chose academic domain for this research, and conducted series of user studies involving University researchers. For initial studies we interviewed and observed researchers to understand how individuals do literature review and synthesize knowledge. For final comparative study, participants were asked to do literature review using a visualization system, called StoryTree. We designed and developed StoryTree system, by analyzing data gathered during initial studies. This visualization system assisted participants during literature review, by facilitating them to organize intermediate literature details visually while reviewing given literature and by generating literature summary at the end of review task. We analyzed summary reports written by these participants using measures of narrative coherence and narrative richness to generate a report quality score. Our analysis shows that reports created with the support

of visualization which implements narrative structure are more coherent and richer compare to the reports generated using visualization, which does not implement narrative structure.

DEDICATION

I could not have completed this work without the love and support of four special individuals. My parents Mr. Suhas Bhangaonkar & Mrs. Suhasini Bhangaonkar who taught me that it is never too late to reinvent yourself. My wife, Sonal Divekar, who shares this achievement with me, during this journey, her love and patience, has always given me constant support and hope. My son Arvin Bhangaonkar, who is my life force and is the one who inspires me to bring the best out of me.

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NOMENCLATURE

HCI/hci	Human Computer Interaction

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1. INTRODUCTION

Sensemaking is the process by which people give meaning to experience. Making sense of a given situation involves an active processing of information to achieve understanding. Such situations involve a common activity of analyzing a body of the given or derived data. As Russell et al define (Russell et. al., 1993), sense making is "a process of searching for a representation and encoding data in that representation to answer task-specific questions". Operations involved during such sensemaking process need different internal and external cognitive resources. One of such resources is a choice of a mental model or schema to represent intermediate data. The choice of mental model may affect the effectiveness of the given information-processing task. (Russell et. al., 1993)

In this research we are interested to find implications of 'narrative structure' used as a mental model to represent intermediate information during knowledge representation phase of sensemaking process. We focus on 'sense making loop' proposed in Pirolli & Card's sensemaking model (Pirolli, P., Card, S., 2005) and examine how each of these mental schemas affects overall quality of the synthesized knowledge over the course of the given sensemaking task. We developed a study investigating students experiencing visualization systems, which implemented either of narrative or hierarchical list structures, for the given information-processing task.

For the purpose of this research we chose 'literature review' as an information-processing task. This task drew literatures from human computer interaction field (HCI)

as a stimulus material. The subfield of 'HCI' that was chosen encompassed embodied interaction topics, such as embodied interaction (Dourish, P., http://www.douri.sh/embodied/embodied99.pdf), embodied cognition (Wilson, M., 2002) and theories of embodiment (Klemmer, S., Hartmann, B., Takayama, L., 2006). Study participants experienced either of two versions of prototyped visualization systems during literature review process, and wrote final summary report to reflect their understanding of the given literature.

We collected feedback and conducted semi structured interviews to gain insight on the use of each structure during literature review process. We analyzed summary on measures, content coherence and content richness to generate a report quality score. Our findings show how narrative structure signifies quality of literature summary report. Based on our findings we discuss significance of narrative structure over sensemaking process.

2. SENSEMAKING

The term sensemaking simply means “the making sense of” (Weick, K. E., 1995). Weick (Weick, K. E., 1995) describes sensemaking as the process of structuring the unknown by placing given stimuli into some kind of ‘framework’, which enables us to find information, interpret it, and organize it into some cogent form, for gaining a comprehension of information. Examples of sensemaking activities include strategizing an approach to solve a puzzle, building a cognitive model to accomplish given task or collaborating to understand a problem.

The concept of sensemaking activity, involves active, iterative interaction with bulk of the information to refine it into forms that provide insight and support effective action. The sensemaking concept has gained a momentum due to various factors such as widely available information on web, library & information science and a push from Human Computer Interaction (HCI) communities. These fields have proposed different sensemaking models, to accomplish domain specific tasks. These different sensemaking models have begun to converge on different projects, trying to help people make sense of the bulk of information resources widely available. (Pirolli, P., Russell, D., 2011). Following section discusses some of these sensemaking models.

2.1. Data/Frame Perspective of Sensemaking

Data/Frame theory has been developed in fields outside of HCI. Klein et al. (Klein, G., Moon, B., Hoffman, R.R, 2006a) propose that situation awareness could be considered a state-of-knowledge about the world, involving some form of mental model

representation of the state of affairs in the world. The Data/Frame theory assumes that meaningful representations called ‘frames’, define what counts as data and how those data are structured for mental processing (Klein, G., Moon, B., Hoffman, R.R, 2006b).

2.2. Collaborative Sensemaking

This sensemaking model is situated in a social context and evolved in the field of Organization Science. Karl Wick et. al (Weick, K., Sutcliffe, K., Obstfed, D., 2005)(Weick, K.,1995) describes sensemaking as “a process that involves turning circumstances into a situation that is comprehended explicitly in words and that serves as a springboard into action”. This model pinpoints central features of sensemaking as - ‘organizing flux’, ‘noticing and bracketing’, ‘labeling’, ‘retrospecting’, ‘presumption’, ‘social and systemic’, ‘acting’ and ‘communicating’.

The model explains role of distributed intelligence, which binds with the sensemaking process. It looks at collaborative sensemaking as a way in which team of people work together to create a collaborative sense of information, to coordinate not just their information sharing but also their intents, their interpretations and revisions of past theories based on newly arriving information.

2.3. Representation Construction Model of Sensemaking

The idea of sense making in the field of HCI in the early 1990s was framed as the process of forming and working with meaningful representations in order to internalize information and subsequent intelligent action. (Pirolli, P., Russell, D., 2011)

2.3.1. Learning Loop Complex

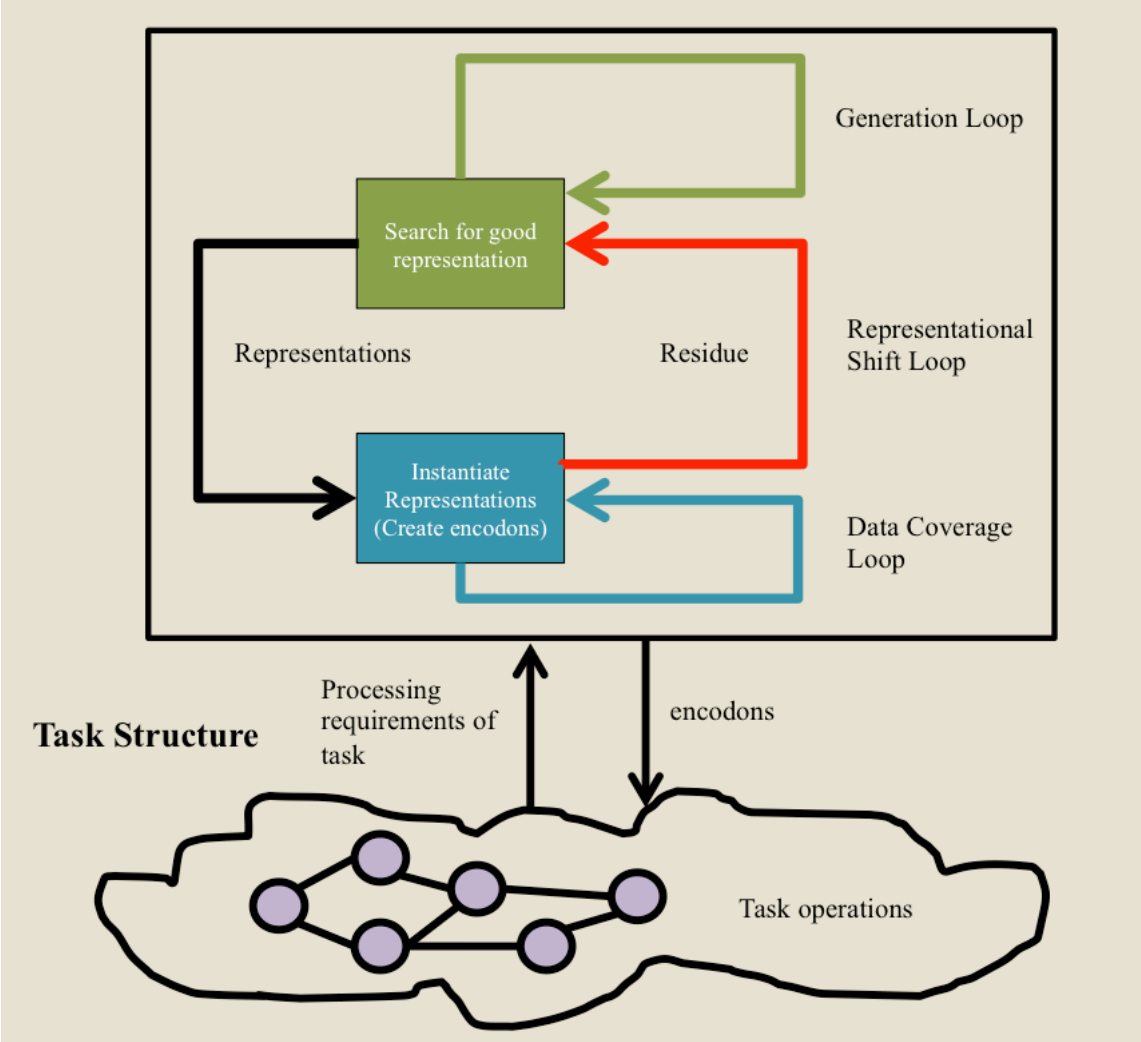

Figure 1 Representation of Learning Loop Complex Theory of Sensemaking (Russell et.al, 1993)

Russell et al (Russell et al, 1993) generalized sensemaking in terms of four key processes (Learning Loops in sensemaking, figure 1), which consists of **searching for representations** (figure 1 - generation loop), **instantiate representations** (figure 1 -

data coverage loop) to instantiate a schema means to use a source of information to find information elements that can be used to fill in the expected information in the fields. The instantiation process involves creating a copy or instance of the schema, locating and extracting the required information, and filling in the information in the expected place, **shift representations** (figure 1 - residue) the attempt at encoding information in the representation identifies items that do not fit and **consume encodons** (figure 1 - encodons) an instantiated schema. In a sensemaking task, a sense maker fills out templates or schemas to capture information. For example, he may fill out elements of a table or fill out forms. The filled out items are called encodons). The result is a more compact representation if the essence of the information relative to the intended task.

2.3.2. Sensemaking Model for Cognitive Task Analysis

Pirolli & Card (Pirolli, P., Card, S., 2005) represent a model of the overall process of sensemaking for intelligence analysis tasks.

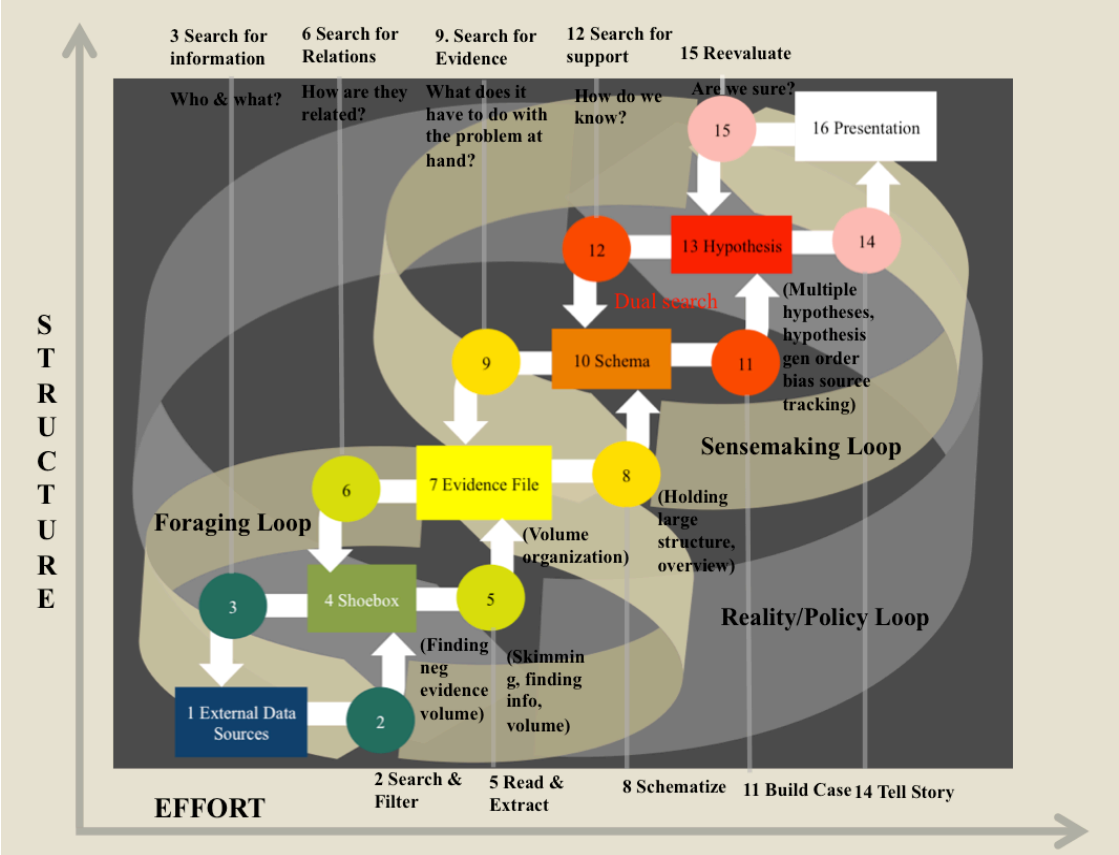

Figure 2 Representation of Pirolli & Card's Sensemaking Loop for Intelligence Analysis (Pirolli, P., Card, S., 2005)

This sensemaking model has two major loops of activities:

Information Foraging Loop - that involves processes aimed at seeking and filtering information, as well as reading and extracting information, possibly placing into some schematic organization framework. (Search process and filtering process - No. 1 to 7 in Sense making mode) (Pirolli, P., Card, S.K., 1999)

Sensemaking Loop - involves iterative development of representational schema that best fit the evidence and provide a basis for understanding the data (Schematizing and telling the story - No. 8 to 15 in Sense making model) (Russell et.al, 1993)

For the scope of this research we focus on ‘sense making loop’. We embed ‘narrative structure’ and ‘hierarchical list structure’ within this loop to examine how each of these structures affect outcome of sensemaking task. We are going to discuss narrative structure in subsequent sections.

3. NARRATIVE SCHEMA IN SENSEMAKING

Our research focus lies in exploring use of narrative structure as a schema to organize and represent information, and its effect over the synthesized knowledge. Following section examines affordance of narrative structure as a mental model to represent information in the knowledge making process.

3.1. Narrative as a Psychological Tool

Branigan asserts, "It (narrative) is one of the fundamental ways to organize data." (Branigan, E., 1992) He describes the importance of stories to the way we understand our world by anticipating and telling ourselves mini-stories about that environment based on stories already told. We use narratives as a strategy for making our world of experiences and desires comprehensible.

Narrative can be seen as an organization of experience, which draws together many aspects of our spatial, temporal, and causal perception. In a narrative, some person, object or situation undergoes a particular type of change and this change is measured by a sequence of attribution, which apply to the thing at different times. We adopt this perception as Herman (Herman, D., 2003) argues that narrative structure can be used as a 'psychological tool' (Vygotsky, L., 1978) to represent and manipulate information objects synthesized during information sensemaking process. Narrative is a way of experiencing a group of sentences or pictures or movements etc. which together attribute a beginning, middle and resolve to something. Herman in his influential work proposes, "narratives afford scaffolding for making sense of experience" (Herman, D.,

2013). He terms this process as ‘Storying the World’; we are going to explore this narrative storytelling model in the following section.

3.2. Storying the World

Herman argues that narratives can be categorized as a socially embedded psychological or cognitive tool. (Herman, D., 2003) He propose a narrative model, which consists of five key processes, **chunking experiences into workable segments -** The process by which the stream of experience is segmented into units that are bounded, classifiable, and thus more readily recognized and remembered, **causal relations between events -** Narrative prototypically roots itself in causal-chronological relations, **managing problem with the typification of phenomena -** A process of creating standard social construction based on standard assumption, **sequencing behavior -** Explaining what exactly should one do, where, when, and in what order? Narrative supports “cognitive mapping” i.e. the process by which things and events are mentally modeled as being located somewhere in the world, and **distributed intelligence across group -** Distributing intelligence across group.

For the scope of this research we use a lens of storytelling model to look at the sensemaking process. We are interested to examine how narrative structure, if used as a mental model affects literature review process and its end product, a summary of the given literature. Following section discuss our research objectives.

4. RESEARCH OBJECTIVES

We propose to investigate implications of 'narrative structure', used as a mental model, during knowledge representation phase of sensemaking process. Based on preliminary study data analysis (see section 7.1.3, 7.2.3) we decided 'hierarchical list structure', to be used as an experimental control for our research study.

4.1. Hypothesis

Our hypothesis is **'Use of narrative structure during literature sensemaking process results in a rich and more coherent summary report than a hierarchical list structure',** and the null hypothesis is 'Use of narrative structure during literature sensemaking process has no effect on summary report'.

4.2. Academic Literature Review, as an Information-processing Task

Based on the prior literature (Paul, S., Reddy, M., 2010) we selected 'academic literature review' as an information intensive task for our study. Subsequent section discuss related work and builds a foundation for the design motivation for the visualizations system we created to test our hypothesis.

5. RELATED WORK*

In order to understand different technology based approaches used to support sensemaking process; we scrutinized seminal work previously done in this area. Following section describes our understanding of some of such systems.

5.1. Visual Knowledge Builder (VKB)

The Visual Knowledge Builder (VKB) is a spatial hypertext workspace for collecting, analyzing and organizing documents (Shipman, F. et. al, 2001); like its predecessor, VIKI (Marshall, C.C., Shipman F., 1995) documents in VKB are represented by visual objects, displaying metadata. These document surrogates are arranged in a hierarchy of two-dimensional spaces called collections. Documents can be placed in a VKB workspace by drag-and-dropping their file icon or document URL. These systems are designed to support emergent qualities of hypertext structures.

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* Parts of this section is used with the permission from Semantic Interaction for Visual Text Analytics, Endert, A., Fiaux, P., North, C., (2012), Proceeding CHI '12 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Pages 473-482, ACM New York, NY, USA ©2012
Emergent Structure in Analytic Workspaces: Design and Use of the Visual Knowledge Builder., Shipman, F., Hsieh, H., Airhart, R., Maloor, P., Moore , J.M., Shah, D., (2001), In INTERACT' 01. 2001:IFIP Technical Committee
Linder, R., Lupfer, N., Kerne, A., Webb, A., Hill, C., Qu, Y., Kade, K., Carrasco, M., and Kellogg, E., (2015). Beyond Slideware: How a Free-form Presentation Medium Stimulates Free-form Thinking in the Classroom, In Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition (C&C '15) ACM, New York, NY, USA, 285-294. DOI=http://dx.doi.org/10.1145/2757226.2757251

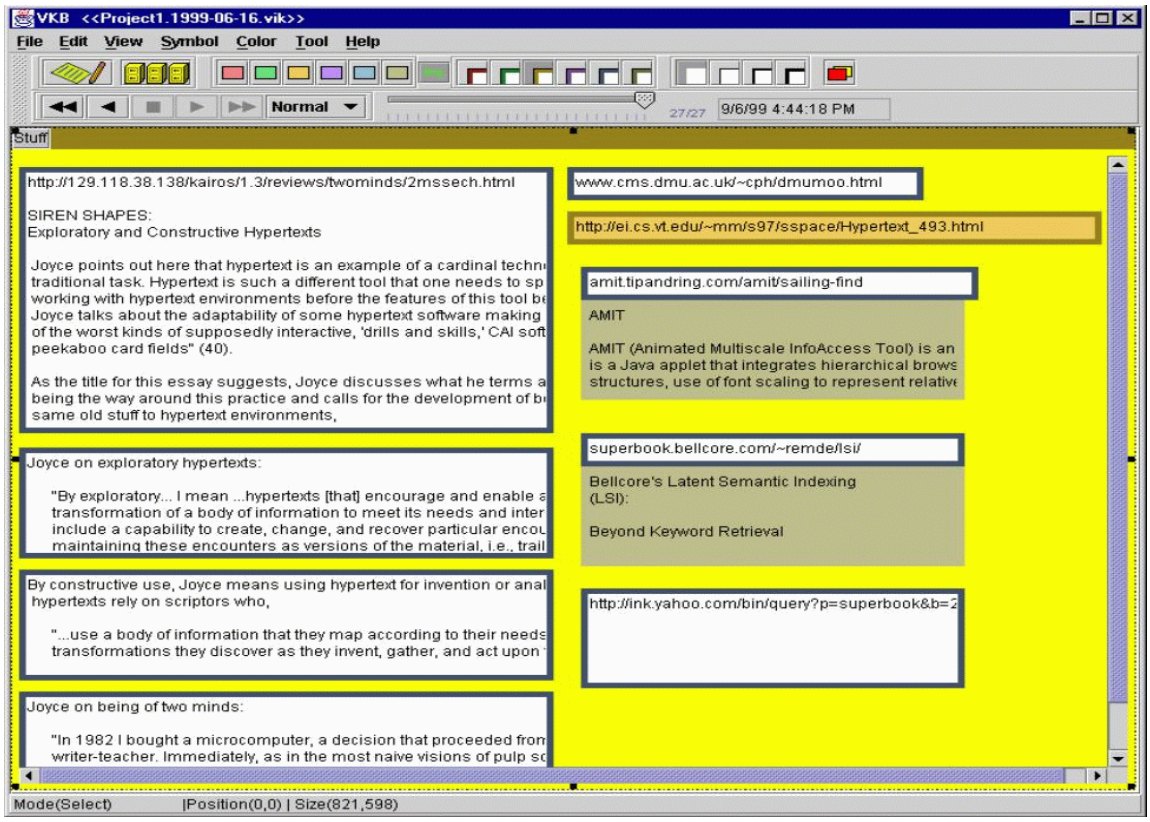

Figure 3 VKB showing organized resources (Shipman, F. et. al, 2001) (Used with permission, refer appendix A.12.1)

VKB also includes a built in search facility for retrieving web documents. Double clicking on a web document object in VKB causes that document to open in the browser. Once documents are within the workspace, users express characteristics and relationships by changing the document objects' visual attributes (background color, border color, border width) and by moving the document objects into lists, piles or different collections. Figure 3 shows one such space after user have organized his contents.

5.2. Semantic Interaction

Visual analytics emphasizing sensemaking of large, complex datasets through interactively exploring visualizations generated by statistical models, a new design space for visual analytic interaction, called Semantic Interaction (Endert, A., Fiaux, P., North, C., 2012). It enables analyst to spatially interact with such models directly within the visual metaphor using interactions that derive from their analytic process, such as searching, highlighting, annotating, and repositioning documents.

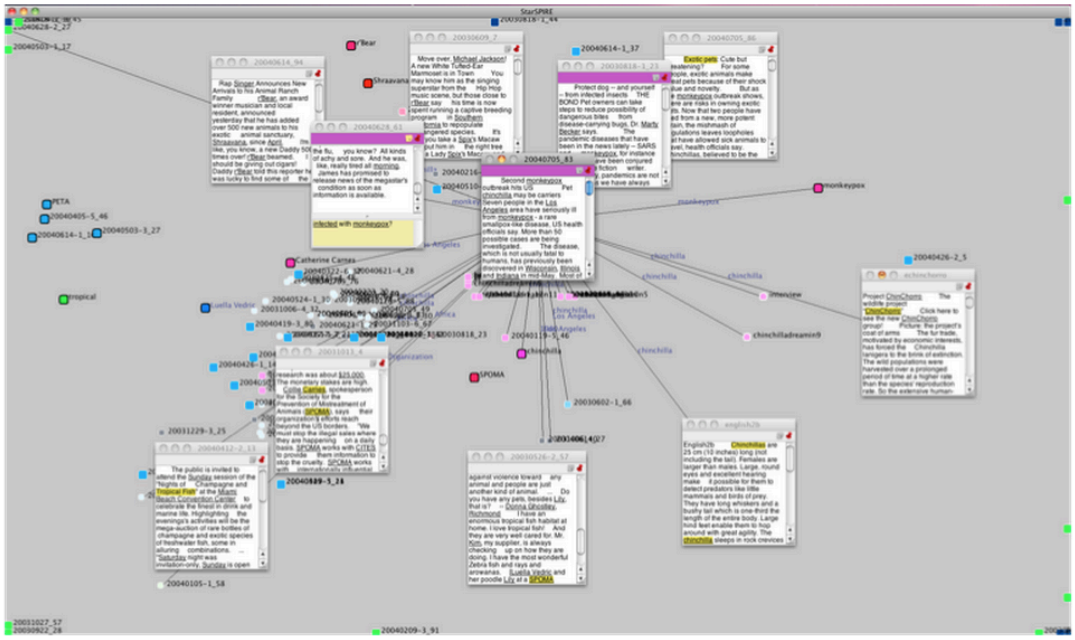

Figure 4 Semantic Interaction showing documents spatially getting arranged for further synthesis (Endert, A. et al 2012) (Used with permission, refer appendix A.12.2)

This system implements the concept of semantic interaction, which lead to a new design space for interaction in spatializations of textual information. It provides an opportunity to unify the sensemaking loop, creating a more seamless analytic process.

5.3. IdeaMache: Free form Web Curation

IdeaMache (Linder, R., Lupfer, N., Kerne, A., 2015) supports free-form presentations in the medium of information compositions, in which elements are gathered from web pages, and assembled to form a visual semantic whole, which is intended to simulate creative cognition of relationships (Kerne, A., Webb, A., 2014). The elements of curation are text, image, video and sound clippings. The forms of annotations are text and sketch. Processes of curation are performed in a web browser. Curations are stored in the cloud, enabling authoring and presenting from anywhere.

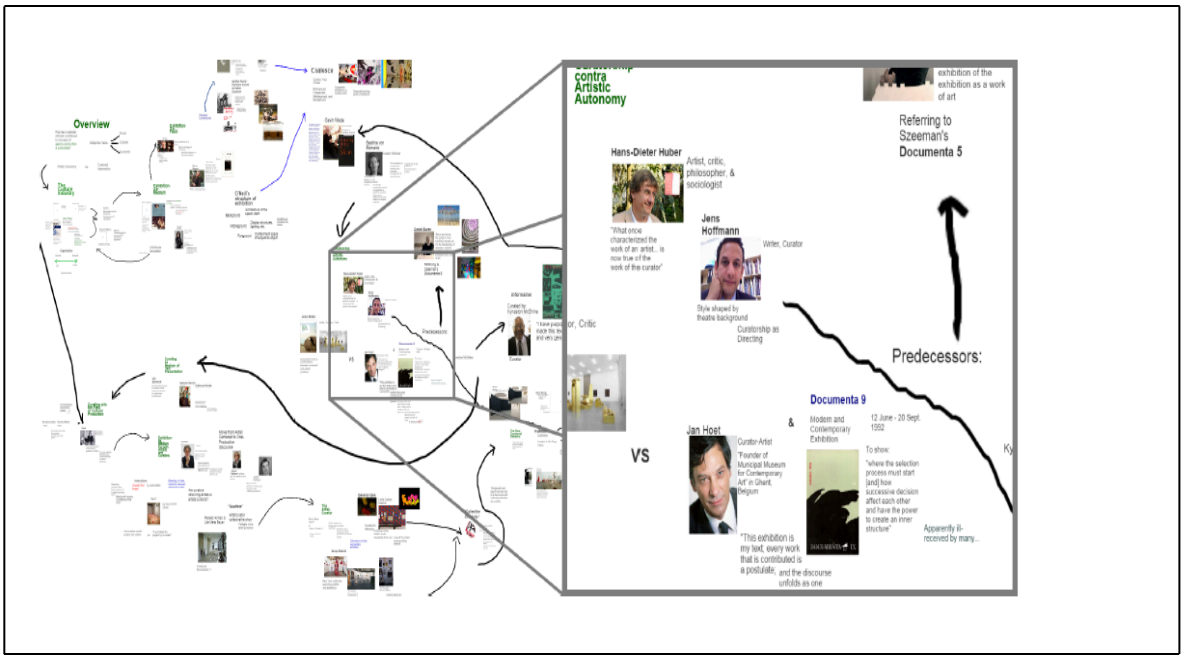

Figure 5 A Student presentation organized using IdeaMache, providing Zoom in and Zoom out views. (Linder, R. et al, 2015) (Used with permission, refer appendix A.12.3)

The notion of IdeaMache is grounded in the free form curation provides pre-inventive structures, which though free-form presentation, simulate free-form thinking, and greater creativity, emergent ideation and responsive discussions in the classroom.

All these systems approach sensemaking in their own ways; these systems are modeled to leverage general sensemaking models we discussed in section 2. Their focus lays in the results these systems facilitate with user interaction.

5.4. Paucity of the Visualization System for this Research

For this research we are also interested in the final results a visualization system would generate, however our focus lays in exploring a specific aspect of the sensemaking process (in this case knowledge representation using proposed schemas) and not just use a sensemaking model (in this case Pirolli & Card's proposed sensemaking model) to build a new information processing system. Existing visualization systems, which are associated with sensemaking process, are designed as a tool to support individuals during sensemaking tasks. Our research needed a custom tool that could help us validate our hypothesis. Based on preliminary data analysis, prior literature and by exploring related sensemaking system, we designed a custom visualization system called **The StoryTree** for our research. Following section discusses StoryTree design and implementation along with the overall research methodology exercised in during this research.

6. RESEARCH METHODOLOGY

This research was conducted in two parts extended over three phases. First part 'Preliminary Study', covered over phase 1 and 2. Second part 'Usability and Comparative Study', covered over phase 3. Preliminary study was instrumental as it afforded scaffolding for constructing our hypothesis. It also helped to synthesize design guidelines for proposed visualization system (The StoryTree). Usability study confirmed system readiness, in terms of usability and comparability of two versions (narrative and hierarchical list) of StoryTree. It also helped us to fix some of generic usability issues, which weren't anticipated during prototyping phase. Comparative study was run as paired tests. Each pair (group) used one version of StoryTree to perform literature review task and generated summary report asserting their understanding of the given literature. At the end summary reports were analyzed along with the other supporting data that was captured during comparative studies to publish results. Subsequent sections discuss each study design, data collection and analysis methodologies implementations in detail.

7. PRELIMINARY STUDY

Preliminary study was done in two phases. Phase 1 encompassed University researcher interviews, and phase 2 covered observations of student groups critiquing a given literature.

7.1. Phase 1

7.1.1. Interviews

For phase 1 of the preliminary study University researchers were interviewed, spanning from undergraduate students to experienced faculty members. Primary objective of this phase was to understand, ‘how individuals do literature review in academic domain’. 13 participants were interviewed from different academic domains. Following table provides participant demographics.

Participant ID	Gender	Department	Expert Level
P1	M	Visualization	High
P2	M	Visualization	High
P3	M	Computer Science	High
P4	F	Architecture	Medium
P5	M	Visualization	Low
P6	F	Visualization	Medium
P7	M	Computer Science	Medium
P8	M	Visualization	Medium
P9	F	Psychology	High
P10	M	Computer Science	Low
P11	F	Computer Science	Low
P12	M	Computer Science	Low
P13	M	Architecture	High

Table 1 Phase 1 – Interview Participants – Demographics

These were semi-structured interviews, interview questions were formed around themes, such as domain of interest, research experience, challenges faced while doing in-field out-field literature reviews, urgency associated with the contextual details, primary sources referenced, types of support system researchers use (and why), literature review methodology and goals. (Refer appendix 13.1, 13.2 for interview questionnaire) A typical scenario-based question was included as a part of interview; the question was

structured in a way to understand 'how individuals pursue references in order to make sense of any unknown terminology they encounter during their literature review'.

7.1.2. Data Collection

These interviews were audio recorded and transcribed (40 hours of transcription) for further data analysis.

7.1.3. Data Analysis & Findings

This transcribed interview data was analyzed using standard qualitative analysis approach. We used **open coding** to determine categories focal points of analysis from the transcribed data. Then used **focus or axial coding** to employ the categories and focus points to derive more refined themes and observations from this phase.

Following themes were derived from phase 1 data analysis.

#	Themes	Codes
1	Understanding	Unfamiliar vocabulary, literature context, domain knowledge, cross references
2	Relevance	Relevance of research, currency of information.
3	Variety of Literature	Types of literature needs to be reviewed
4	Duration of literature review	Time taken to review literature
5	Organization	Organization of the information (house keeping work)
6	Searching	Use of right search terms, scope of

Table 2 Phase 1 - Interview – Themes

These themes were used as a lens to analyze phase 2 data. Phase 2 Group study will be discussed in the next section.

7.2. Phase 2

7.2.1. Group Study

The study enabled to video record set of students critiquing project proposals in a graduate level research methodology class. As a part of their class assignments, students were asked to list five pros and cons for a given project proposals. Goals of this study was to understand ‘how individuals make sense of given literature’, ‘what methodologies they use to arrive at a conclusion’, ‘what challenges do they face during literature review and how they overcome these challenges’

Figure 6 Participants discussing Project Proposals during Group Study

Following table provides study participant demographics.

Participant Id	Gender	Group Id
P1	M	1
P2	M	
P3	M	
P4	M	
P5	M	
P6	M	2
P7	M	
P8	M	
P9	M	
P10	F	
P11	F	3
P12	M	
P13	M	
P14	M	
P15	M	
P16	F	
P17	M	4
P18	M	
P19	F	
P20	F	
P21	F	

Table 3 Phase 2 Group study Participants – Demographics

We took a formal approval from an instructor and students to video record this class. There 21 students who attended this session. All these students were graduate students at Department of Visualization.

7.2.2. Data Collection

We video recorded four groups. The session lasted around 2 hours 30 minutes on an average. All videos were transcribed (20 hours of transcription) for further data analysis.

7.2.3. Data Analysis & Findings

By the end of this study over 120 GB of both quantitative and qualitative data was collected, **selective coding** was used to analyze transcribed video data. Themes from phase 1 analysis were used to perform focused coding on the video data. Based on our research focus we used (phase 1) themes such as ‘understand’, ‘relevance’, ‘variety of literature’, ‘duration of literature review’, ‘organization’, and ‘partial resource access and searching’.

Following table shows the trends observed for group study data analysis.

	Understanding	Relevance	Organization
G1	29	2	1
G2	12	1	1
G3	22	0	5
G4	8	1	1
Total	**71**	**4**	**8**

Table 4 Phase 2 - Group Study – Trends

We did not observe any themes associated with ‘variety of literature’, ‘duration of literature review’, and ‘partial resource access and searching’ during this analysis.

We used data analysis from preliminary study and understanding from the prior literature to propose a prototyping design, which is discussed in next section.

8. PROTOTYPING

Based on the prior literature review and phase 1 & phase 2 data analysis we structured our prototype design. We used full prototyping approach, implementing all the proposed functionalities.

8.1. System Design

Following section discuss the system design and implementation of the **StoryTree** prototype we build for this research.

8.1.1. Systems Use Case Diagram

Use case diagrams present an outside view of the manner the elements in a system behave and how they can be used in the context. Use case diagrams are used to model the context of a system by enclosing all the activities of a system within a rectangle and focusing on the actors outside the system by interacting with it. Following use case diagram provides a view of the way StoryTree elements would interact with the StoryTree users.

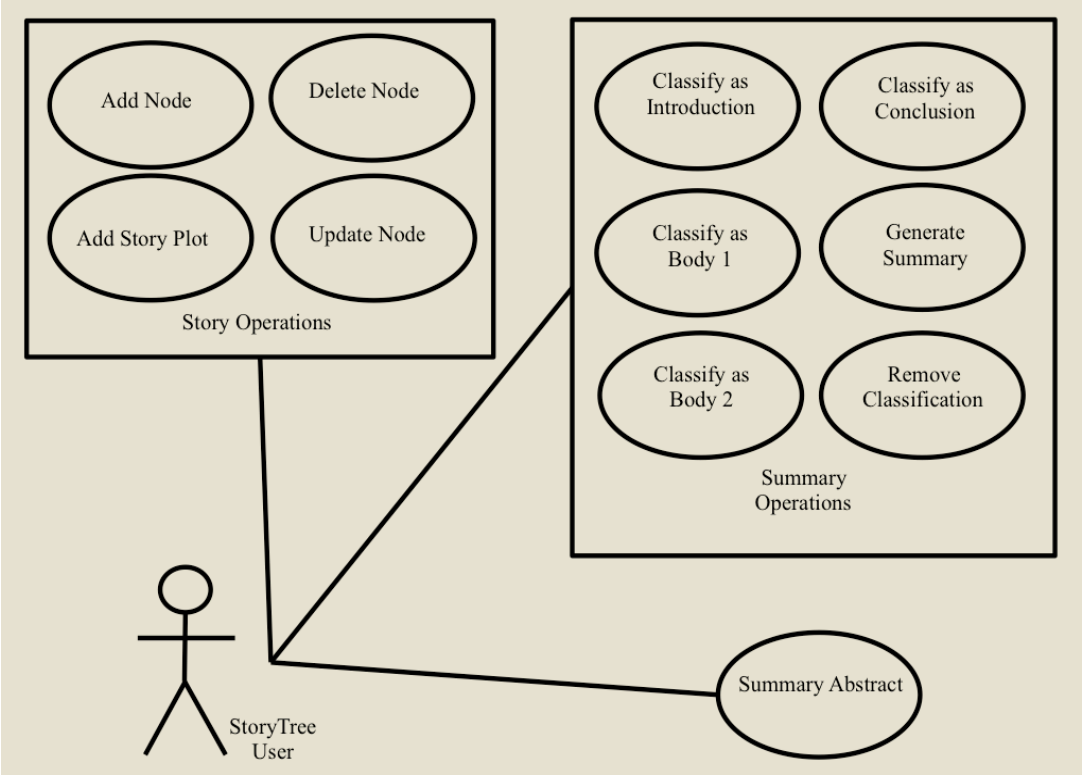

Figure 7 StoryTree Use Case Diagram

The use case diagram shows an actor (a stick figure), it's a StoryTree user. The solid lines shows relationships and ovals represent use cases. StoryTree has three main components, 'Story Operations', 'Summary Operations', and 'Summary Abstract'. Story Operations are used to create a story tree, which holds relevant literature review details. Summary operations are used to classify these details either as introduction or body or conclusion and to generate Summary abstract. StoryTree generates summary abstract by processing the way user have classified story details. User can access this summary abstract for future processing.

8.1.2. System Sequence Diagram

Following figure presents a StoryTree sequence. It presents an order of interaction, which occurs between objects.

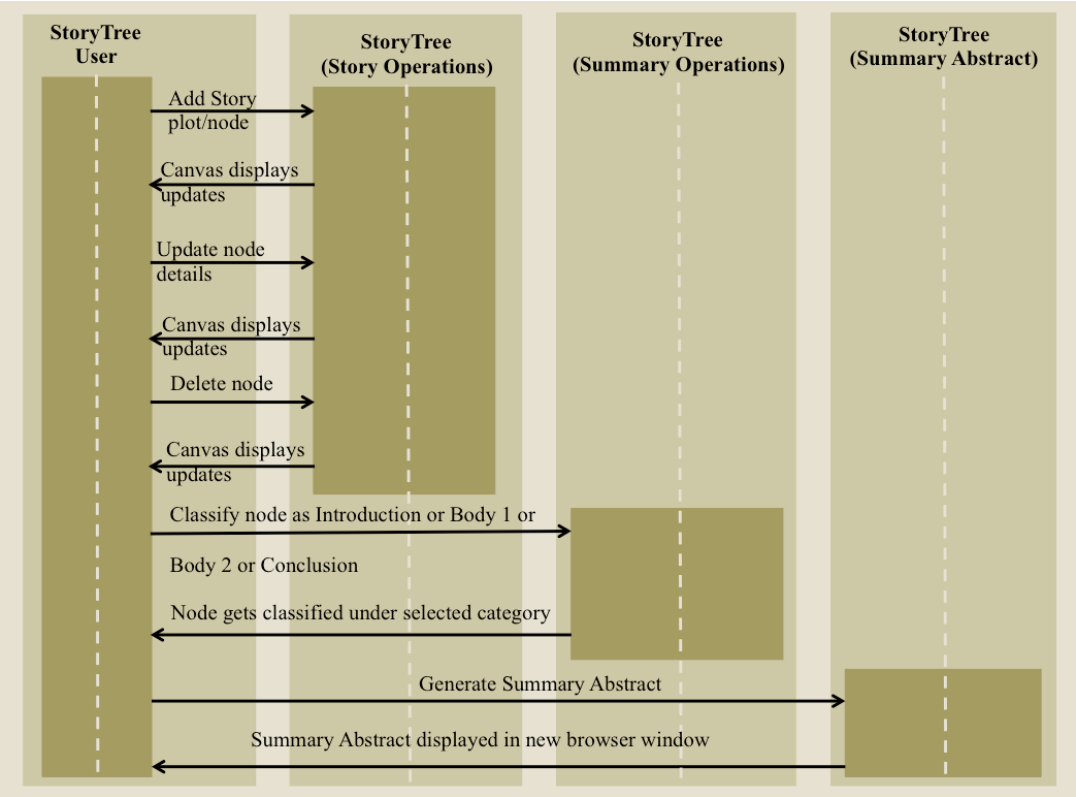

Figure 8 StoryTree – Sequence Diagram

StoryTree user began his interaction using ‘story operations’, these story objects (literature details) are then classified using summary operations and at the end summary abstract is generated.

8.1.3. Systems Overview

Following figure provides StoryTree layout details. StoryTree layout comprised of two tabs and a canvas. Tabs afford StoryTree users to perform story operation such as adding, deleting or updating nodes, and summary operation such as classify nodes as introduction or body 1 or body 2 or conclusion, and generate summary. These operations help user to capture relevant literature details during his literature review. StoryTree generates a summary abstract, which is presented to the user in a new browser window.

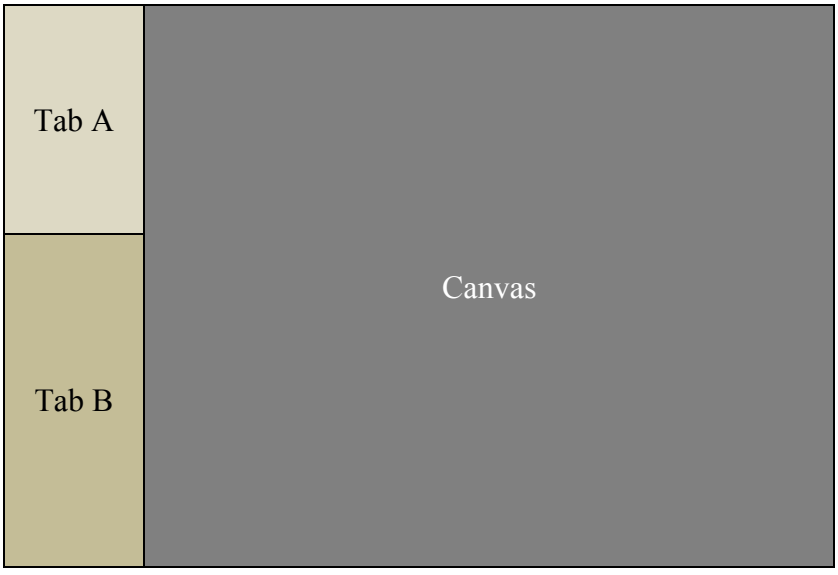

Figure 9 StoryTree Layout 1

Following sections step by step describes each component of StoryTree system.

In **Tab A** (figure 9) StoryTree includes story operations. These operations allows user to create and alter story tree by adding node or story plot, updating or deleting nodes. Figure 10 (A) shows Story Operations component of 'narrative' StoryTree version, and figure 10 (B) shows Story Operations of 'hierarchical list' version.

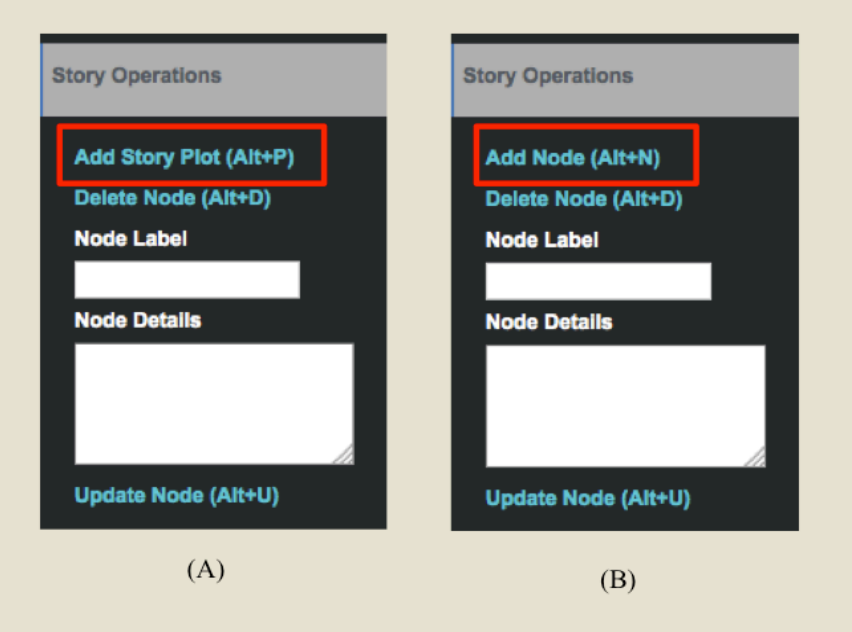

Figure 10 StoryTree Tab A - Story Operations

Note the difference between these two versions of story operations, ‘narrative’ version (A) allows user to add ‘Story Plot’, which is a narrative structure that contains ‘introduction, middle and end’, where as ‘hierarchical list’ version (B) allows user to add individual nodes to the story tree. User can select any node and get it updated using ‘Update Node’ option and node can be deleted using ‘Delete Node’ option.

In **Tab B** for both narrative and hierarchical list versions, StoryTree provides ‘summary operations’. These operations are used to classify nodes as either as introduction, body 1 or body 2 or conclusion.

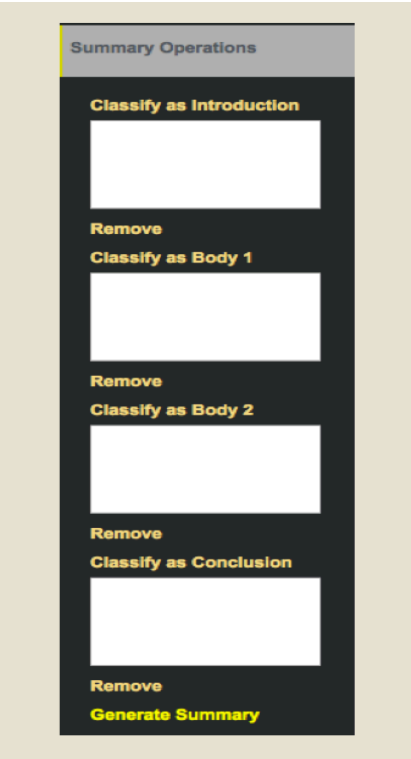

Figure 11 StoryTree Tab B - Summary Operations

Multiple nodes can be selected from visualization presented on StoryTree canvas. These nodes can be selected and categorized to either of the category by clicking on the category link e.g. ‘Classify as Introduction’ or ‘Classify as Conclusion’. User can remove a specific node from the category list, with the help of Remove option provided at the bottom of the multiple select list components. Once classification of nodes completed, user can use ‘Generate Summary’ option to generate summary abstract, which is then presented in figure 15. The **canvas** section provides visualization for either of the narrative structure (figure 12) or hierarchical list (figure 13) structure. Based on operations performed by user, this tree structure alters itself. Each node can be selected for add, update or delete story operation.

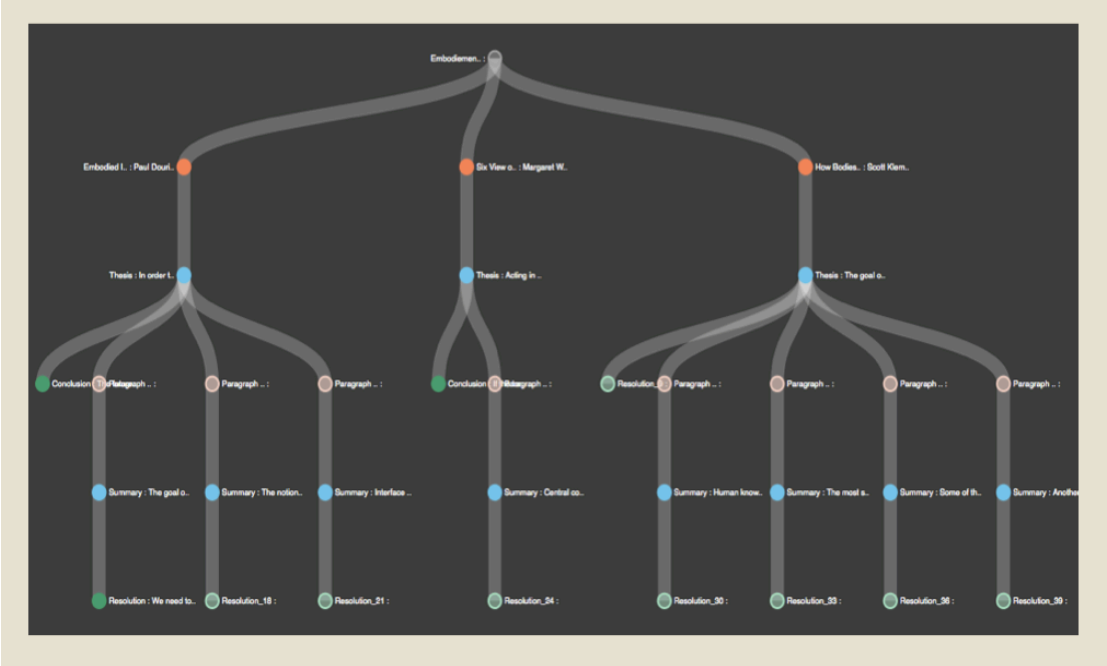

Figure 12 StoryTree Canvas - Narrative Structure

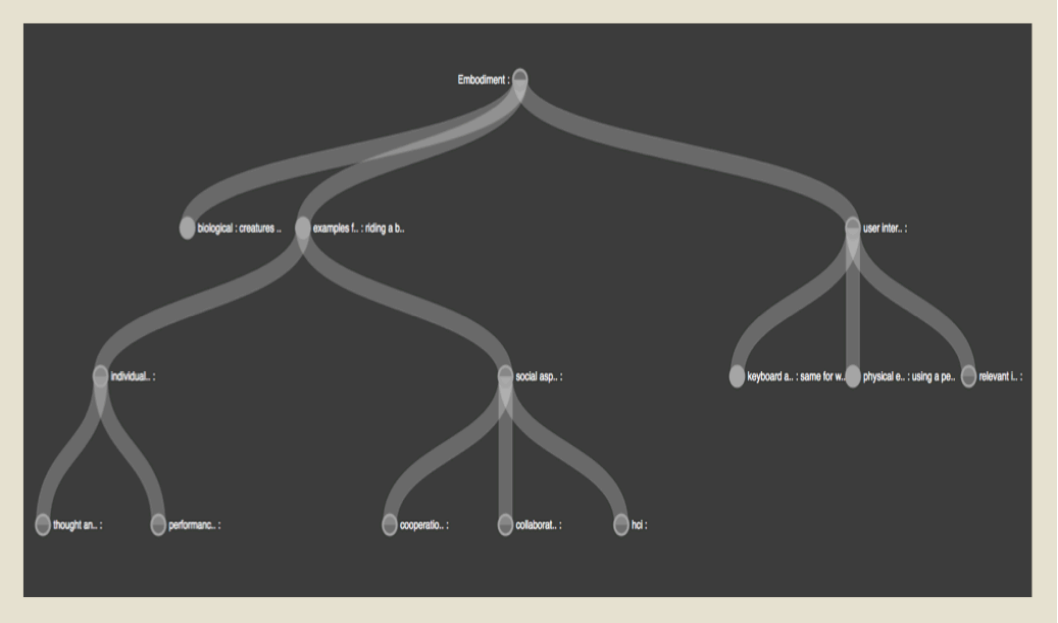

Figure 13 StoryTree Canvas - Hierarchical List Structure

The final step of the StoryTree use is to generate **summary abstract,** as user hits 'Generate Summary' link under Summary operations tab; StoryTree builds a summary abstract using summary categorization user assigned during summary operations. This summary abstract is presented to the user in a new browser window.

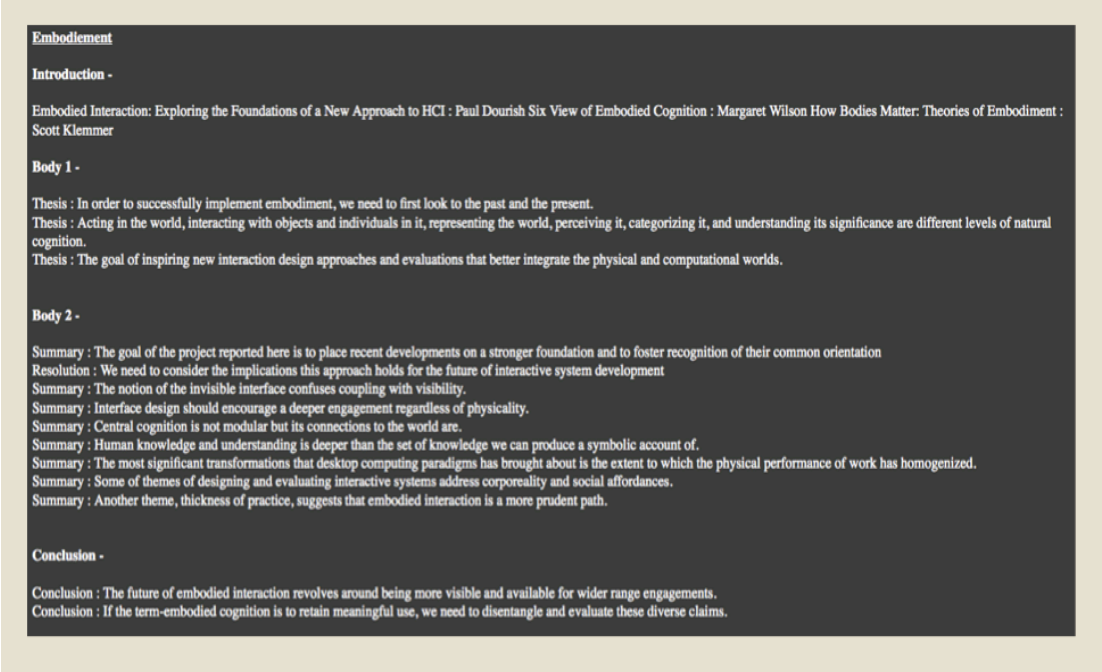

Figure 14 StoryTree Summary Abstract

As user click 'Generate summary', StoryTree consolidates all story objects and present them as a summary abstract.

Final summary report was a part of the study where participants use summary abstract as a reference to write a formal summary of the given literature to reflect their understanding of the given literature.

Embodied Interaction: Exploring the Foundations of a New Approach to HCI: Paul Dourish

In order to successfully implement embodiment, we need to first look to the past and the present. The goal of the project reported here is to place recent developments on a stronger foundation and to foster recognition of their common orientation
We need to consider the implications this approach holds for the future of interactive system development. The notion of the invisible interface confuses coupling with visibility. Interface design should encourage a deeper engagement regardless of physicality. The future of embodied interaction revolves around being more visible and available for wider range engagements.

Six View of Embodied Cognition: Margaret Wilson

Acting in the world, interacting with objects and individuals in it, representing the world, perceiving it, categorizing it, and understanding its significance are different levels of natural cognition. Central cognition is not modular but its connections to the world are. If the term-embodied cognition is to retain meaningful use, we need to disentangle and evaluate these diverse claims.

How Bodies Matter: Theories of Embodiment: Scott Klemmer

The goal of inspiring new interaction design approaches and evaluations that better integrate the physical and computational worlds. Human knowledge and understanding is deeper than the set of knowledge we can produce a symbolic account of. The most significant transformations that desktop computing paradigms have brought about are the extent to which the physical performance of work has homogenized. Some of the themes of designing and evaluating interactive systems address corporeality and social affordances. Another theme, thickness of practice, suggests that embodied interaction is a more prudent path. These themes represent the different aspects of human embodied engagement and how interaction design integrates the physical and computational worlds.

Figure 15 Summary Reports - Written by Study Group

User copy past summary abstract in a word processing software and use it as a template or reference to generate final summary report.

8.2. System Implementation

Considering the portability for implementing StoryTree system we chose web platform. We have used HTML5.0, d3.js (d3js), bootstrap.js (getbootstrap) libraries to build StoryTree framework. StoryTree test bed was deployed on the web server hosted by Texas A&M University. The StoryTree layout explained in system overview (section 8.1.3) was designed to fit in to single web page. Thus we built two versions of StoryTree, one implemented 'narrative structure' and other which implemented 'hierarchical list structure'. These two versions were hosted as separate web pages as indexp.html and indexc.html. Based on which version is being used by the study group, we fetched either of these web pages. Following section presents phase 3 studies and discusses study analysis and findings.

9. USABILITY STUDY

As a part of a phase 3, we conducted usability study with six participants. These participants were mix of undergraduate and graduate students. These students were randomly chosen from visualization, psychology and computer science departments. The goal of usability study was to test the readiness of StoryTree system versions and to test the comparability of 'narrative' and 'hierarchical list' versions of StoryTree systems. We ran 'within subject' tests asked each participant to use each StoryTree version one after other.

Following table shows the order details used in this study.

Participant ID	**StoryTree Version**	
P1	N	C
P2	C	N
P3	N	C
P4	C	N
P5	N	C
P6	C	N

Table 5 Usability Study Order details, 'N- Narrative, C- Hierarchical List' Structure

Following table presents study protocol and the time taken by each activity. Table lists the main activities proposed in the study protocol. Usability protocol comprised of five steps.

#	Task Details	Time (Min)
1	Briefing	10
2	System walkthrough	10
3	Practice Session	15
4	System use and analysis	30
5	Post-study questionnaire and interview	5
	Total Time	70

Table 6 Usability Study Task Details

In **briefing** participants were given sufficient time to review consent form, ask questions regarding study, once they provided their consent, they were briefed about the study, and expected study tasks. We presented each StoryTree version (one at a time) during **system walkthrough.** We explained system functionality and had a brief question answer session regarding system operations. Participant was given **practice session,** during which each participant was asked to perform a specific task such as add, delete or update node, generate summary. The objective of the practice session was to provide participants hands on experience of the StoryTree system. During **system use and analysis,** participant was then given a stimulus material (refer appendix 13.4), an abstract taken from 'Reality based Interaction' paper by (Jacob, R., et. al., 2008), as the focus of this study was to test usability, we used same stimulus material for both system versions ignoring the effect of familiarity factor, while use of second version in the order. The study was counter balanced. We made observations, to note any specific user and system behavior e.g. use of short cut feature instead of explicit button click, any system generated errors. At the end of the study participant was asked to provide feedback using **post-study questionnaire and interview.** We adapted IBM usability questionnaire (Lewis, J., R., 1993) to ask structured questions based on the overall usability satisfaction, to be rated on the scale of 1 (strongly disagree) to 7 (strongly agree) (refer appendix 13.5)

Participant performed tasks 2 to 5 for both StoryTree versions, thus usability study lasted around on average of 2 hour 15 min per participant.

9.1. Data Collection

9.1.1. Interview

Each participant was asked to rate his comfort level at using digital technology and web applications, before starting this study. For the post study we asked participant regarding their over all experience. These interviews were audio recorded for further analysis.

9.1.2. Survey

As explained in section 9.2.5 we gave our participant to fill a usability questionnaire to capture the overall ‘user experience’, of working on both StoryTree types.

9.1.3. Data Logging

The StoryTree system was enabled with the data-logging feature, where it captured and logged user actions such as adding, deleting, updating nodes, classifying these nodes etc. It logged both state of the system and state of the summary operations. These logs are ‘state log’ and ‘summary log’. **State log** presents the trace of user interaction with the StoryTree system e.g. when and where node has been added or deleted or updated. Following is an example of state log

"{"0":["p_5",{"id":4,"parent":"null","children":[3,5],"depth":0,"name":"Story Name", "sname": "Story

Name","type":"root","desc":"","sdesc":"","isIntro":"0"},{"id":3,"parent":4,"children":[2],"depth":1,"name":"Introduction_0","sname":"Introduction_0","type":"intro","desc": "","sdesc":"","isIntro":"1"},{"id":5,"parent":4,"children":[6],"depth": ……..

Summary log presents the activities and the sequence of activities user performed under summery operations, following presents summary log example.

...{"id":6,"parent":5,"depth":2,"name":"Thesis","sname":"Thesis","type":"middle","des c":"Acting in the world, interacting with objects and individuals in it, representing the world, perceiving it, categorizing it, and understanding its significance are different levels of natural cognition.","sdesc":"Acting I n ...

These logs were formatted in such a way that they can be used to reconstruct user activities if desired.

9.1.4. Observation Notes

We took observation notes to record evident patterns, unique situations participants encountered, while they were interacting with the given system. We used these observations to fix some of the system issues such as noticeable problems such as feature to unselect system nodes, a feature which was added after usability study based on these observations. We also noted process related issues in order to fine tune our study protocol, e.g. how to explain certain functionality, what order of explanation works or does not work etc.

9.2. Data Analysis and Findings

Following chart provides comparison for usability ratings for visual systems implementing narrative structure (N) and hierarchical list structure (C). The means were not significantly different. ($p = 0.1878$)

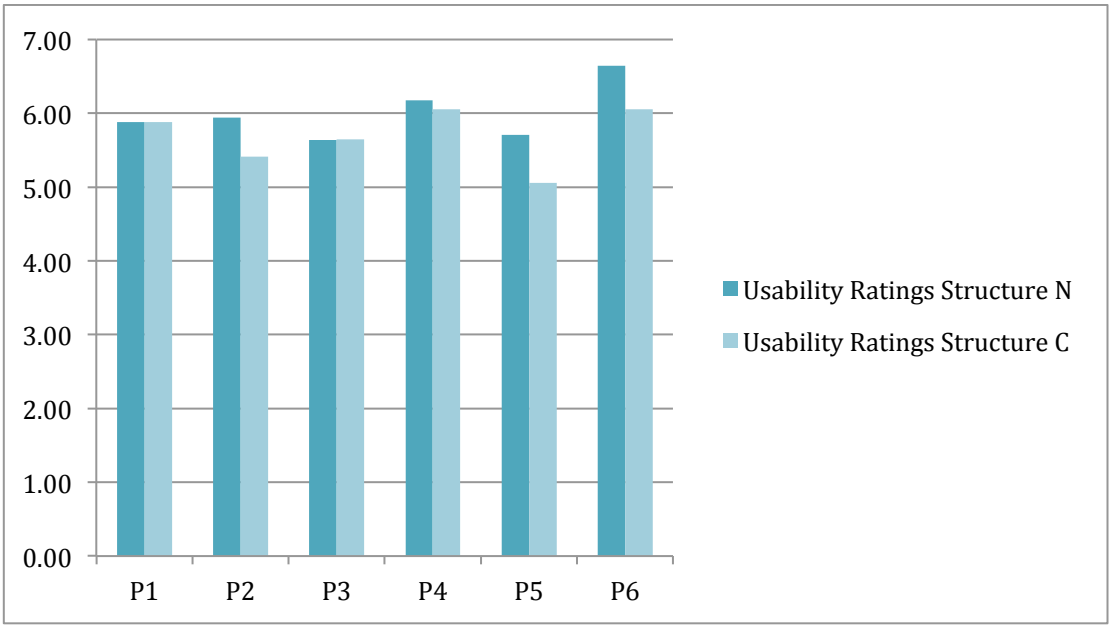

Figure 16 Usability Rating comparisons for the Narrative (N) version and Hierarchical List (C) version

Participant	Usability Ratings	
	Structure N	Structure C
P1	5.88	5.88
P2	5.94	5.41
P3	5.64	5.65
P4	6.18	6.06
P5	5.71	5.06
P6	6.65	6.06
Average Rating	6.00	5.69

Table 7 Usability rating values for StoryTree systems Narrative Structure (N) and Hierarchical List Structure (C)

Based on the usability feedback, we fixed functionalities **story tree operations -** updated node would retain focus. Prior usability study, system was setting control back to the project node after node was updated. **Summary operations -** selected node could be unselected. Prior usability study this feature was absent. **Study protocol -**We also refined our practice session approach, and it is discussed in Comparative study sections in next section.

10. COMPARATIVE STUDY

10.1. Comparative Study

We conducted a qualitative study of the manifestation of sensemaking using StoryTree versions. The inquiry was to seek which version supports better story quality. We used Berman's model (Berman, R., 1988) for evaluating story coherence and news narrative paradigm (Gupta, V.S., 2003) to calculate story richness. These measures calculated story score, which was used to compare the story created by study groups. The participants were 12 visualization and computer science students in an undergraduate and graduate class. Participants were classified in six groups. Following table provides demographics and the order in which these pairs used respective StoryTree versions.

Groups	Structure Used	P1		P2	
		Gender	Domain	Gender	Domain
G1	C	M	Computer Science	M	Visualization
G2	N	M	Computer Science	M	Visualization
G3	C	M	Visualization	M	Computer Science
G5	N	M	Visualization	M	Computer Science
G6	C	F	Computer Science	M	Computer Science
G7	N	F	Computer Science	M	Computer Science

Table 8 Comparative Study participant Demographics, C- Hierarchical List Structure, N-Narrative Structure.

The study was counter balanced. Following table provides the study protocol.

#	Task	Task Details	Time (Min)
1	Briefing	Consent	15
		Study Overview	
		Pre-study Questionnaire	
2	Leisure Activity	Ice breaking activity- Lego house	10
3	System Walkthrough	System functionality walk through	10
		System related Question Answers	
4	Practice session	Sample literature review using system support	20
		Summary report writing	
5	Study Task	Collaborative literature review using system support	60
		Summary report writing	
6	Post Study Interview & Feedback	Post study personal interview	15
		Post-Study Questionnaire	
	Total Time		**130**

Table 9 Comparative Study Protocol

Briefing - Participant group was briefed about the study after they provided their consent. They were asked to rate their 'literature review expertise', 'familiarity of HCI field' on the scale of 1 (low) to 7 (high) (refer to appendix 13.7). **Leisure Activity -** The study group was asked to build Lego house in 10 minutes. It was an ice breaking activity for participants to get acquainted with each other.

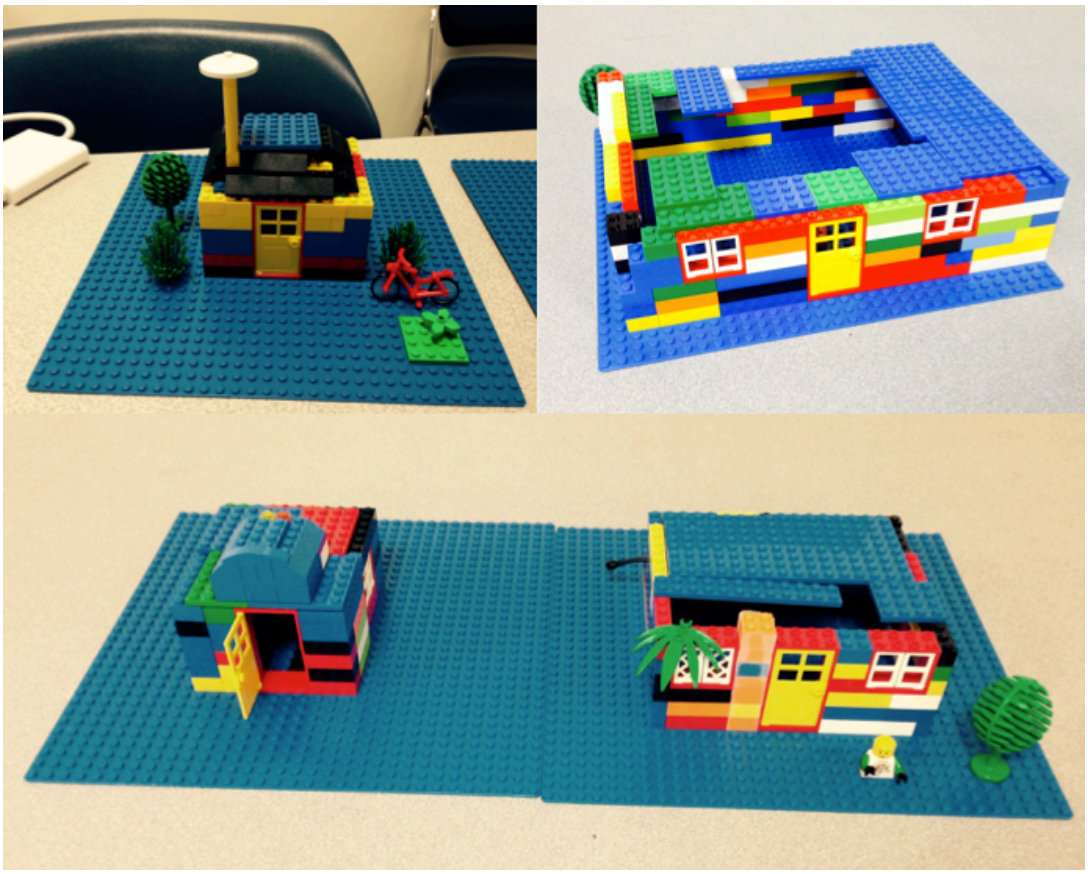

Figure 17 The Comparative Study Group Lego Houses

System Walkthrough - Study group was given 10 minutes of system walkthrough. **Practice session -** 20 minutes were given to study group individuals for practice session. This was a hands on experience for participants to use given StoryTree version and produce a summary report for a given stimulus material (literature mentioned in 9.2.4 was used as a practice stimulus material). They used individual laptops (either Windows or OSX) to connect to StoryTree server to access StoryTree (either narrative or hierarchical list) version. By the end of 20th minutes they were asked to stop practice session, irrespective of whatever state it was. The objective of this session was to expose study participants to the whole study process. **Study Task -** Participants were given a stimulus material (refer appendix 13.6). These were abstracts taken from three embodied interaction papers. (Klemmer, S., 2006), (Wilson, M., 2002), (Dourish, P., http://www.douri.sh/embodied/embodied99.pdf) Study group was asked to work in collaboration for 60 minutes, to do literature review using StoryTree system, to collect relevant details and form a summary report of the given literature stimulus material. As described in section 8.1.3 StoryTree helped study group to create a summary abstract. The study group then used this summary abstract to write their final summary report. **Post study interview and feedback -** At the end of the study task, each participant were given a questionnaire (explained in section 10.2.2.) to provide feedback on aspects such as overall system usage, process effectiveness, final summary report satisfaction etc. Each participant was asked to appear for a semi-structured interview. The interview questions were based on the theme like "what approach did participant used to generate summary report? What were participant thought about the process used during the study

and structure implemented by the StoryTree system? Whether participant was satisfied with the summary report he/she generated? Why?"

10.2. Data Collection

Following sections provides details of each data collection method.

10.2.1. Interview

Each participant was interviewed at the end of his or her study participation. These interviews were conducted on the basis, one participant at a time. We asked them to recall their approach for generating final summary report. We asked them to comment on their experience with the given system and the structure (narrative or hierarchical structure) it implemented. We asked them if they were satisfied with their final report and why? (Appendix 13.11) Interviews were audio recorded and transcribed for further analysis (3 hours of transcription)

10.2.2. Survey

We adapted IBM usability questionnaire (Lewis, J., R., 1993) to ask structured questions based on the overall usability satisfaction, process satisfaction and report satisfaction to be rated on the scale of 1 (strongly disagree) to 7 (strongly agree) (refer appendix 13.8,13.9,13.10).

10.2.3. Data Logging

The StoryTree system was enabled with the data-logging feature, as explained in 9.3.3 where it captured and logged user actions such as adding, deleting, updating nodes, classifying these nodes etc.

10.2.4. Video Recording

We video recorded this study session. We had two objectives for this type of data captures style. First objective was to observe what process pair uses in order to work on the given literature review task, discussion, and overall approach. Second objective was to observe how they interact with the give system.

10.3. Data Analysis & Findings

We use both quantitative and qualitative modes to collect this study data. We used this approach for data collection; since we argued that just quantitative analysis alone wont be sufficient for us to analyze our hypothesis, we coupled quantitative measures with qualitative channels. By the end of this study we ended up collecting over 123 GB of both quantitative and qualitative data.

Following sections discuss the approach we used to analyze our study data.

10.3.1. Quantitative Analysis

As explained in section 10.2.2 we collected participant feedbacks on the overall usability, process and report on different aspects such as satisfaction, effectiveness, efficiency, coherence, richness etc.

10.3.1.1. Pre-study Data Analysis Findings

We asked participants to report their ‘prior experience of doing literature review’ and their ‘familiarity of HCI field’. We wanted to observe if this would put any influence on the quality of report these individuals would create. Following charts provide ‘experience with literature process’ and ‘HCI familiarity’ details

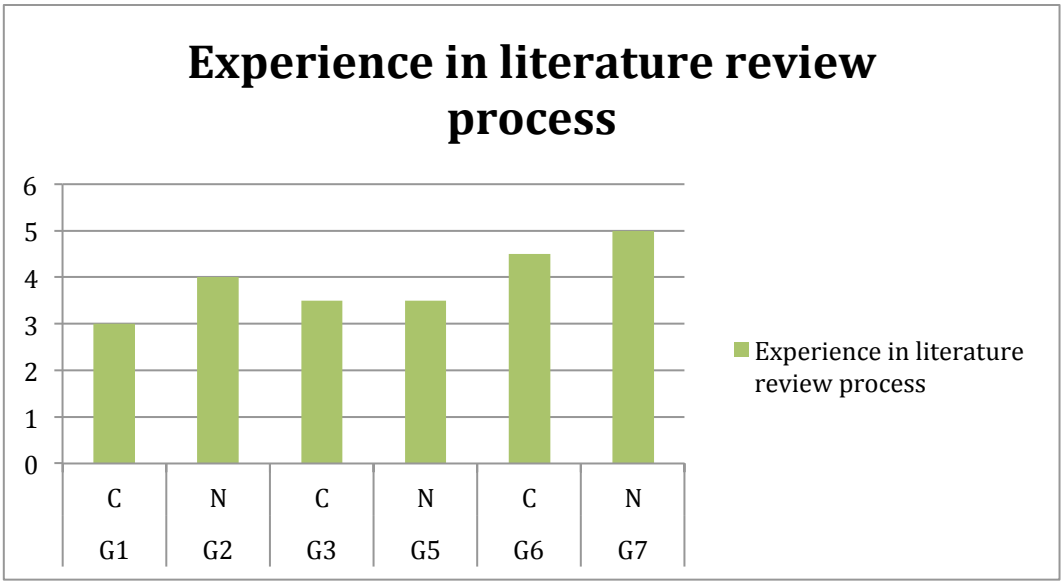

Figure 18 Experiences in Literature Review Process

Groups	Structure Used	Experience in literature review process
G1	C	3
G2	N	4
G3	C	3.5
G5	N	3.5
G6	C	4.5
G7	N	5

Table 10 Experience in Literature Review Process values

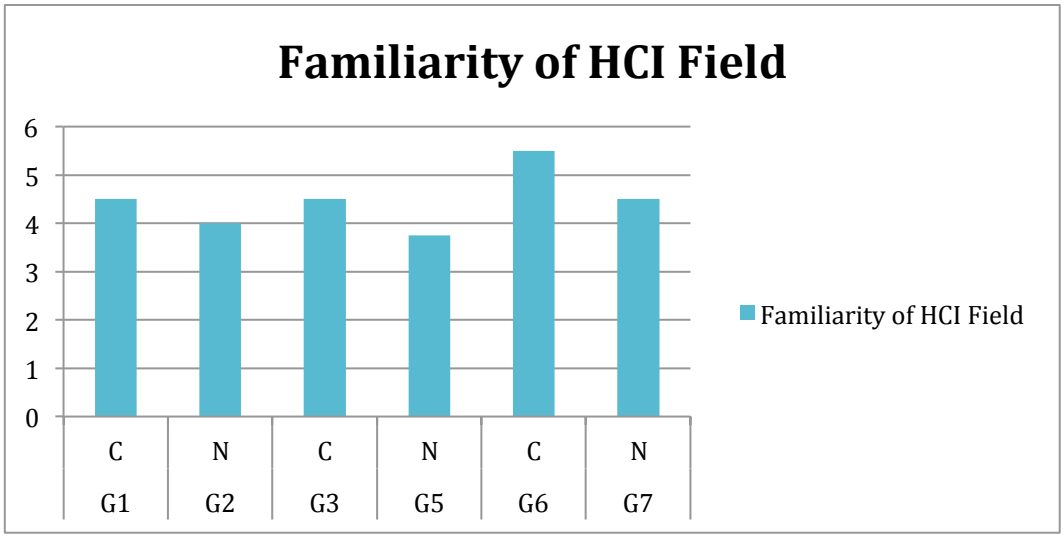

Figure 19 Familiarity of HCI field

Groups	Structure Used	Familiarity of HCI Field
G1	C	4.5
G2	N	4
G3	C	4.5
G5	N	3.75
G6	C	5.5
G7	N	4.5

Table 11 Group HCI Familiarities

10.3.1.2. Post-Study Quantitative Data Analysis & Findings

We collected an average data point for each group, and used all these data points for statistical analysis. We used IBM SPSS for our quantitative analysis. We used participant's 'experience with literature review process' and 'familiarity with HCI field' as covariates in this analysis.

The usability means were not significantly different (p = 0.265), Narrative version (mean 5.9) and Hierarchical List version (mean = 4.91).

10.3.2. Qualitative Analysis

Qualitative analysis for comparative study was two folds. We used selective coding to analyze interview and video data collected from comparative study. We also used a coding methodology grounded in narrative theory to evaluated summary reports generated by study groups.

10.3.2.1. Interview Data Analysis

We used a focused coding methodology to analyze post study interviews. Some of the self reported behavior patterns are discussed in the discussion. We used interview data analysis to provide a rational to certain patterns we observed during summary report analysis. We will be presenting these results under ‘discussion’ section.

10.3.2.2. Summary Report Analysis

To device an approach to evaluate summary report, we adopted evaluation methodology used by Chu, S. et al. (Chu, S., Quek, F., 2013) and by Boltman (Boltman, A., Druin, A., 2001) in their study evaluation to evaluate stories created by children. Following sections provides our understanding of narrative coherence & narrative richness and coding methodology we used for evaluating these measures, in order to evaluate summary report.

10.3.2.2.1. Narrative Coherence

Narrative coherence was understood as the need for 'both the parts of the story and the story as a whole hang together in a convincing and satisfying way'. It concerns assessing the centering of a story as well as the sequence of events narrated. Berman (Berman, R., 1988) proposed a coding scheme to assess the narrative structure of children's stories based on measurements such as the number of references to plot advancing events, the number of references to plot summations and the types of connectivity markers.

Using this understanding, we define **Idea Unit** as a single unit of a comprehensible sentence. **Story Block** as a set of idea units connected by causal connectors, and **Episode** as set of story blocks with a logical flow, which follows a narrative structure of beginning, middle and resolution. For the scope of this research we calculated **Causal Connectors** (cause and effect), in each idea unit, which are connectivity markers that connects words, phrases and clauses.

10.3.2.2.2. Narrative Richness

Narrative richness has proposed to assess story retelling through 'holistic grading', which functions on the premise that, 'the whole of any piece of writing is greater than the sum of its parts'. One thus has to take into account the 'total impress' of the text, however we did not adopt this procedure, since it did not fit our purpose. As we wanted more objective consistent method that could enable us to evaluate how much the group has fleshed out the narratives with relevant contextual information, we borrowed evaluation approach from news narratives. The analysis comprised of identifying how

many idea units addressed 'who, what, when, where, why and how' contained with in each story block.

10.3.2.2.3. Story Score Calculation

We established following protocol to determine **Story Score** for the given summary report, where **Story Score is a sum total of Narrative Coherence and Narrative Richness**

- Determine independent Story Blocks in a given summary report
- Determine Story Block type (Introduction, Middle, Resolution)
- Determine number of Episodes in a given summary report.
- Break each Story Block in to independent Idea Units
- Determine Causal connectors.
- Determine Idea quality (adjective such as meaningful, significant etc.)
- Determine richness of each Idea unit based on if given idea unit provides meaningful information in terms of Who, What, Why, When, Where and How.

E.g. Elements of summary report example

Following illustration presents how a given episode can be broken into Story Block and Idea Units, and how Causal connectors are identified.

Episode

How Bodies Matter: Theories of Embodiment: Scott Klemmer. The goal of inspiring new … Human knowledge and understanding is deeper than the set of knowledge we can produce a symbolic account of. …….. **These themes represent the different**

aspects of human embodied engagement and how interaction design integrates the physical and computational worlds.

Story Block

"These themes represent the different aspects of human embodied engagement and how interaction design integrates the physical and computational worlds."

Idea Units

"These themes represent the different aspects of human embodied engagement."

"How interaction design integrates the physical and computational worlds."

Causal Connectors

"And"

Narrative Coherence was calculated as sum total of all the Story blocks, Causal connectors.

Narrative Richness was calculated as sum of Idea quality units and richness units.

Following tables provide objective details of each summary report.

Groups	Structure Used	Number of Introduction Sections	Number of Middle Sections	Number of Resolution Sections
G1	C	1	0	0
G2	N	1	0	0
G3	C	1	0	1
G5	N	1	1	1
G6	C	3	0	2
G7	N	3	3	3

Table 12 Objective Details Introduction, Middle, and Resolution per Summary

Groups	Number of Introduction Sub Sections	Number of Middle Sub Sections	Number of Resolution Sub Sections	Number of Causal Connectors
G1	0	2	2	3
G2	1	3	2	7
G3	1	2	1	5
G5	2	2	2	9
G6	0	6	0	8
G7	0	8	1	10

Table 13 Objective Details – Sub Sections for Introduction, Middle, Resolution and Causal connectors

Following charts presents ‘narrative coherence’, ‘narrative richness’, and ‘episode per summary report’, ‘Total number of Idea Units’ and ‘story score’ comparisons between study groups.

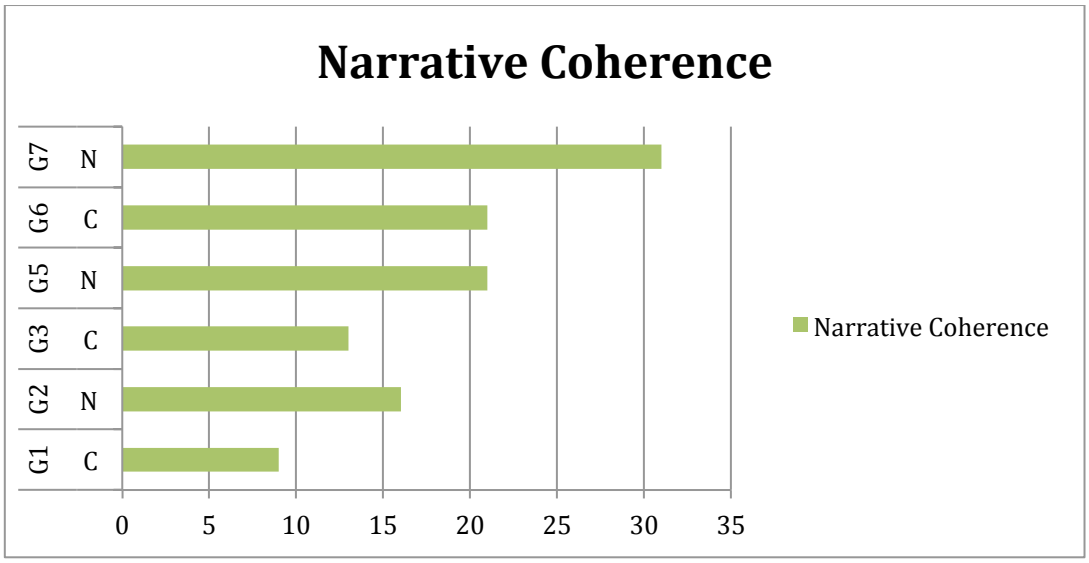

Figure 20 Narrative Coherence Scores

Groups	Structure Used	Narrative Coherence
G1	C	9
G2	N	16
G3	C	13
G5	N	21
G6	C	21
G7	N	31

Table 14 Summary Report Coherence Score values

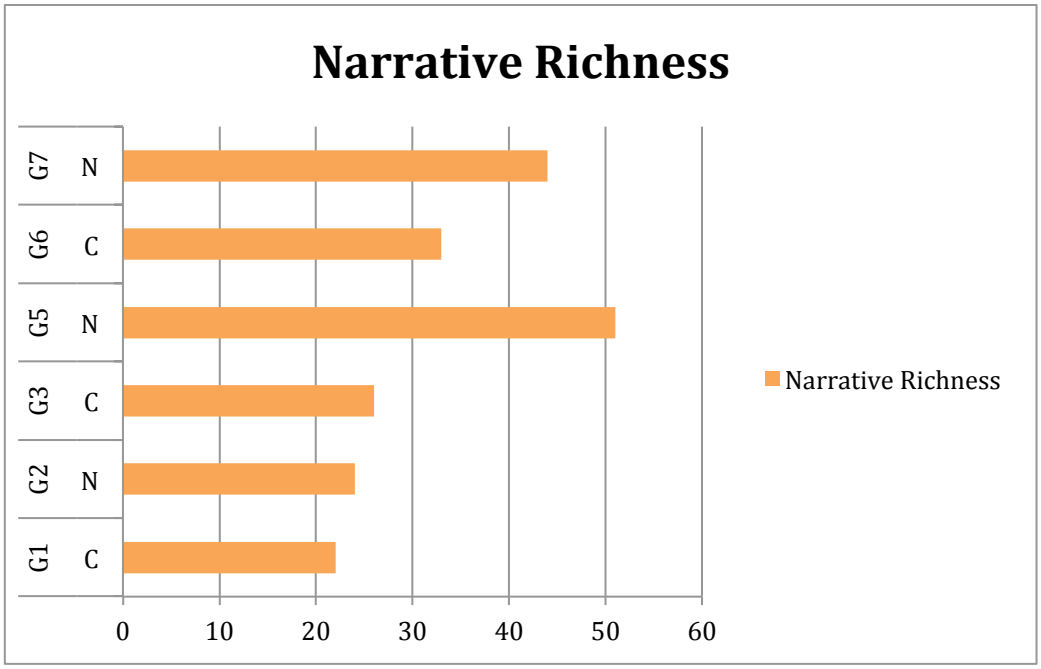

Figure 21 Narrative Richness Scores

Groups	Structure Used	Narrative Richness
G1	C	22
G2	N	24
G3	C	26
G5	N	51
G6	C	33
G7	N	44

Table 15 Summary Report Richness Score values

Overall trend showed that for both narrative coherence and richness study groups, which used narrative structure scored better than groups used list structure

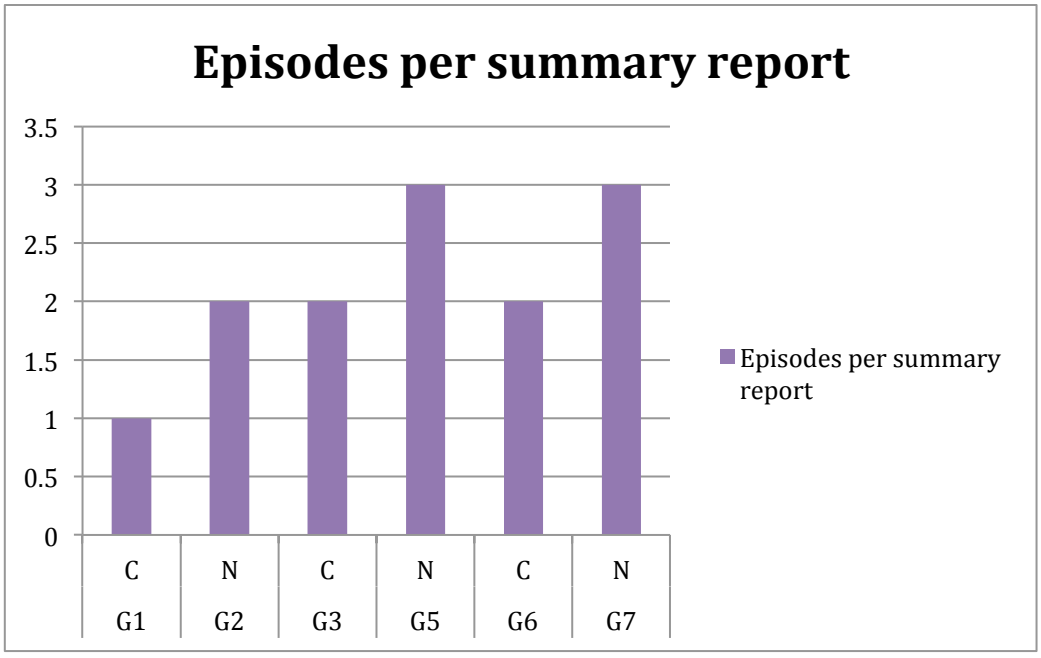

Figure 22 Numbers of Episodes per Summary Report

Groups	Structure Used	Episodes per summary report
G1	C	1
G2	N	2
G3	C	2
G5	N	3
G6	C	2
G7	N	3

Table 16 Numbers of Episodes per Summary Report

Narrative structure based summary reports observed to have more structured form.

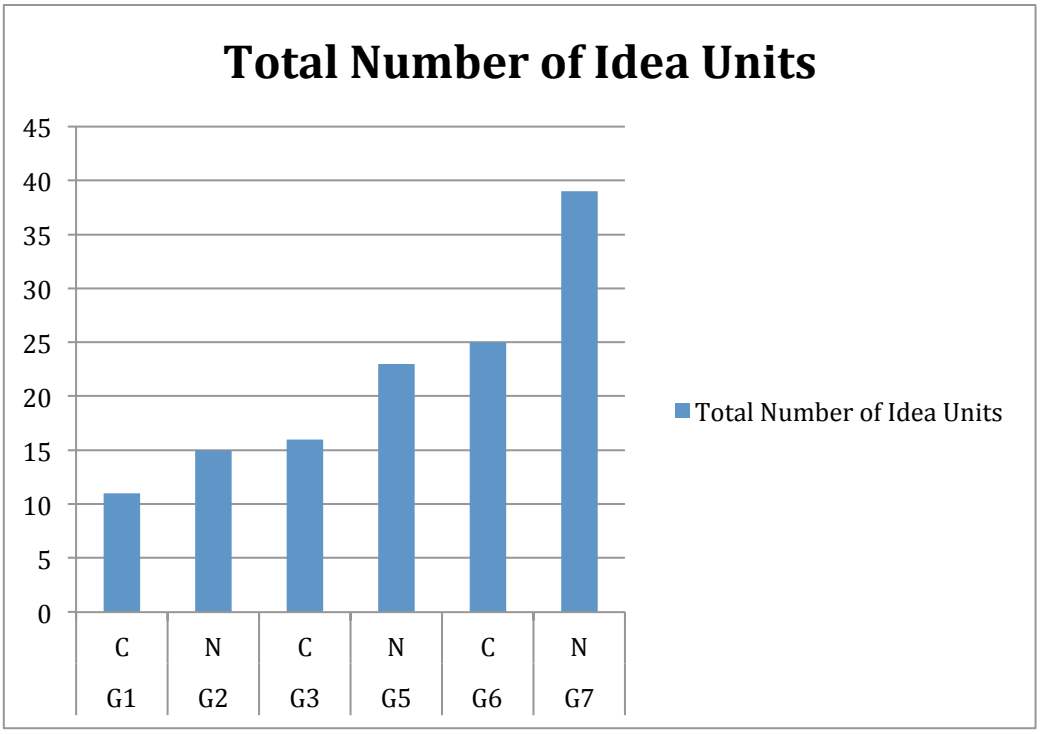

Figure 23 Total Number of Ideas generated per Group

Groups	Structure Used	Total Number of Idea Units
G1	C	11
G2	N	15
G3	C	16
G5	N	23
G6	C	25
G7	N	39

Table 17 Total Number of Ideas generated per Group Values

Narrative structure based summary reports observed to result more idea units.

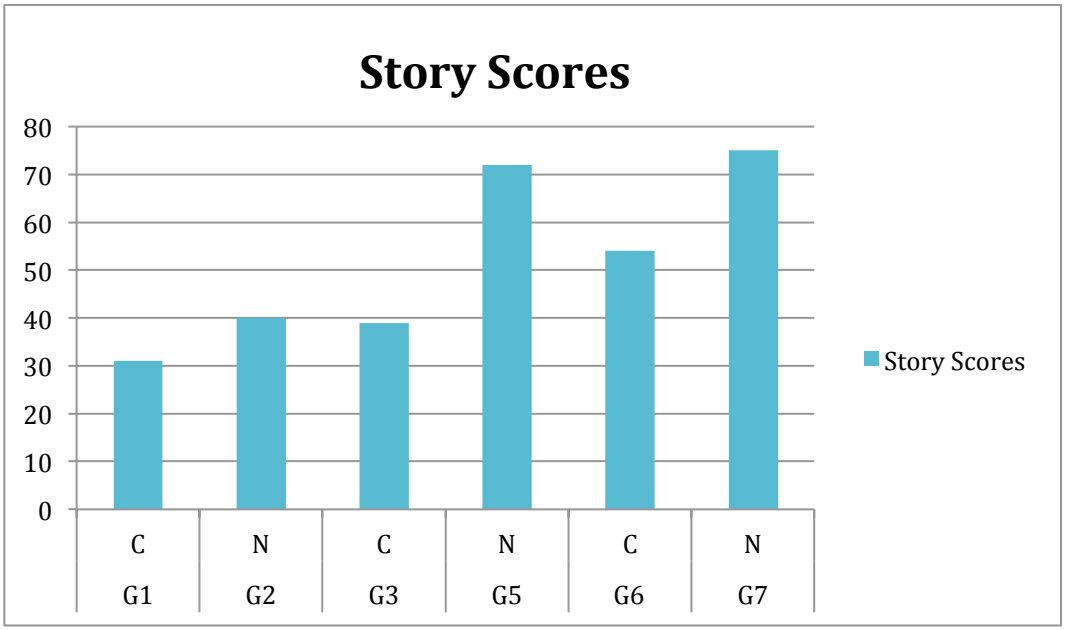

Figure 24 Story Scores

Groups	Structure Used	Story Scores
G1	C	31
G2	N	40
G3	C	39
G5	N	72
G6	C	54
G7	N	75

Table 18 Summary Report Story Scores

Summary scores of the study groups, which used narrative structures, were observed to be better than their counter parts.

11. DISCUSSION

During analyzing of post comparative study interviews, we observed that, study participants reported activities such as skimmed reading, discussion, focused reading, using StoryTree to capture literature details, representing literature details with the help of StoryTree interface, generating summary abstract and writing final summary report using system generated summary abstract as a reference. When these sequential activities were mapped to the Pirolli and Card's model (section 2.3.2), it was evident that participants were actually following **information foraging loop** and **sensemaking loop** described in Pirolli and Card's model

We observed better story scores for the summaries written with the help of 'narrative' system version, (as shown in the figure 24), when compared with the story scores of the summaries written with the help of 'hierarchical list' system version. One of the participants (**G7P1**) exclaimed, **"**The structure automatically kind of forces you to summarize key points"

Participants who used 'narrative' system version reported to like it compare to 'hierarchical list' system. We can deduce that they preferred 'narrative structure' compared to 'hierarchical list structure', since both system versions were comparable on the basis of their functionalities. One of the participants **(G7P2)** reported, "After using this I would use something similar during study … like afterwards this product ever becomes available I will definitely see myself using it."

We did observe certain limitations of StoryTree versions and also the limitations from participant's point of view. For the comparative study presented in this work, we managed to get less number of participants than expected. Thus the sample size is too small to make any generalized statement based on presented data analysis. Participants suggested having operations, such as cross-linking nodes structures or moving node structures, which may help perform better foraging activity. Current StoryTree version does not implement these functionalities, which were reported as constraints by some of these participants. Some of the participants reported that they found it challenging to accept the literature review methodology we suggest during this study, since they were quite comfortable with the traditional approach (using pen & paper) of doing literature review. We plan to address some of these challenges in our future work by continue to run comparative study with more number of participants, to get more data points.

12. CONCLUSION

We presented a study, which help us to examine use of narrative structure during knowledge presentation phase of sensemaking process, and its effect on the knowledge synthesis. We began with questions ‘how individual perform literature review?’, ‘how they make sense of given literature?’, we used a systematic approach of by interviews and observations to craft a high level question ‘what role does narratives play in sensemaking process?’. We chose Pirolli and Card’s sensemaking model for our research, and used a narrative as a lens to scrutinize this sensemaking model. We focused our research on the question ‘how does use of narrative structure during knowledge representation phase of sensemaking affects synthesized knowledge quality’.

We proposed a prototyping visualization system, which, helped us to validate our hypothesis, and during our data analysis we observed that in academic literature review process, approach that individual used, to perform literature review can be mapped to Pirolli and Card’s sensemaking making model.

We did observe that data gathered from our studies does favor our hypothesis ‘use of narrative structure during literature sensemaking process, results better story quality’.

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APPENDIX A

A.1 Preliminary Study - Phase 1 – Interviews

A.1.1 Themes

The objective of this study was to understand, what was “contextual detail” according to given participant, how they do literature review, what challenges they face during literature review process and how do they overcome such challenges.

- **Themes -** Emerging themes for this study session are as follows –

- **Domain -** What are the domains of interests?

- **Challenges -** What challenges does individuals face while foraging in field OR out-field references?

- **Urgency -** How does individual categorize urgency of contextual details?

- **Primary sources -** What are the primary sources individual uses for sense making process?

- **Types of Support -** What types of device support individual take during process of literature review?

- **Methodology -** What are the methodologies for literature review?

- **Goals –** What are individual's goals for doing literature review?

A.1.2 High-Level Question

Following questions were designed on the above-mentioned themes.

- What is your domain of study? Such as Architecture or Computer science or Psychology etc.
- Which domain of study do you address the most?
- How long have you been doing research in general?
- For any given project, how much time do you dedicate for a literature review in terms of hour/day/weeks/months?
- On the scale of 1 to 10 how good you think you are in literature review? And to whom do you compare with?
- For a given project, how do you do literature review?
- What are fields of interest of for which you do literature review?
- What kind of literature do you usually follow? (Journals, Papers, books etc.)
- How often do you do out of field literature review?
- What challenges do you face for out of field literature review, in terms of sense making for a given text?
- What kind of support material do you use during literature review process? (E.g. physical/digital books, using specific devices e.g. desktop, tablet etc.)
- What types of information generally do you highlight during review process?

- How do you teach your students, to do literature review?

A.1.3 Scenario Based Question

Take a minute to review how do you do a literature review. Imagine you are reading a paper for an arbitrary project, and you come across a key phrase, how do you pursue references in order to make sense of this key phrase?

Follow up questions for scenario-based questions

- What methods do you use to look for such key phrases?
- How much time do you spend on cross-referencing?
- How do you keep track of the knowledge generated during such pursuit?
- How do you categorize importance of these references (what needs to read immediately OR can be read in future)?
- What types of notes do you take during review process? What tools (digital devices/pen-paper) do you use to take notes?
- What kind of support would you like to have in order to keep track of references you take while doing literature review?

A.2 Preliminary Study - Phase 1 – Interviews Questionnaire

Preliminary Study Phase 1 Interview Questionnaire

Participant # Date: _____/_____/_____

Demographics

Gender: Male Female

Experience Level

- o Professor
- o Assistant Professor
- o Associate Professor
- o PhD students,
- o Senior graduate student [2nd OR Nth year]
- o Graduate Student [1st year]
- o Undergraduate Student

Domain

- Architecture,
- Visualization,
- Computer science,
- Education,
- Psychology

A.3 Preliminary Study - Phase 2 – Group Study Approach

This section presents the approach we planned for group study.

The objective of this phase is to observe graduate students attending Research Methodology class (at Department of Visualization, School of Architecture, TAMU), and take notes during their group discussion session. The class will be critiquing each other's group project proposals, which will be created as a part of class assignment. The session will be video recorded, and then will be coded for further analysis. Consent from class instructor and students would be taken prior to running this study. The data will be kept privately and confidential.

Notes and observations will be taken during this session and will broadly cover following measures

- How students collaborate to understand a research document (in this case project proposals)?
- What process group/individual followed in order to make sense of the given document/s?
- How did group/individual collect references/cross references, what approach were used?
- Level of granularity, depth of details being explored
- Extent of clarity group and the members of the group have for a given literature.
- How does class as a whole and each individual understand, how literature based research is being done?
- How well students have implemented this understanding in their proposal writing and critiquing task?

A.4 Usability Study - Phase 3 – Stimulus Material

We used abstracts from 'reality based interaction' (Jacob et al, 2008) paper, in order to create a stimulus material for our usability study. We also used this stimulus material during comparative study practice session. Following abstracts presents the stimulus material used in the usability study.

Reality Based Interaction: A Framework for Post WIMP Interfaces

We are in the midst of an explosion of emerging human computer interaction techniques that redefine our understanding of both computers and interaction. We propose the notion of Reality-Based Interaction (RBI) as a unifying concept that ties together a large subset of these emerging interaction styles. Based on this concept of RBI, we provide a framework that can be used to understand, compare, and relate current paths of recent HCI research as well as to analyze specific interaction designs. We believe that viewing interaction through the lens of RBI provides insights for design and uncovers gaps or opportunities for future research.

Over the past two decades, HCI researchers have developed a broad range of new interfaces that diverge from the "window, icon, menu, pointing device" (WIMP) or Direct Manipulation interaction style. Development of this new generation of post-WIMP interfaces has been fueled by advances in computer technology and improved understanding of human psychology. Defined by van Dam as interfaces “containing at least one interaction technique not dependent on classical 2D widgets such as menus and icons”, some examples of these post-WIMP interaction styles are: virtual, mixed and augmented reality, tangible interaction, ubiquitous and pervasive computing, context aware computing, handheld, or mobile interaction, perceptual and affective computing as well as lightweight, tacit or passive interaction. Although some may see these interaction styles as disparate innovations proceeding on unrelated fronts, we propose that they share salient and important commonalities, which can help us understand, connect, and analyze them.

We believe that all of these new interaction styles draw strength by building on users' pre-existing knowledge of the everyday, non-digital world to a much greater extent than before. They employ themes of reality such as users' understanding of naïve physics, their own bodies, the surrounding environment, and other people. They thereby attempt to make computer interaction more like interacting with the real, non-digital world. By drawing upon these themes of reality, emerging interaction styles often reduce the gulf of execution, the gap between a user's goals for action and the means to execute those goals. We propose that these emerging interaction styles can be understood together as a new generation of HCI through the notion of Reality-Based Interaction (RBI). We believe that viewing interaction through the lens of RBI might provide insights for design and uncover gaps or opportunities for future research.

We use the term "real world" to refer to aspects of the physical, non-digital world. However, the terms real world and reality are problematic and can have many additional, interpretations, including cultural and social reality. For that matter, many would also consider keyboards and mice to be as much a part of today's reality as any non-digital artifact.

Thus, to clarify, our framework focuses specifically on the following four themes from the real world:

- Naïve Physics: people have common sense knowledge about the physical world.
- Body Awareness & Skills: people have an awareness of their own physical bodies and possess skills for controlling and coordinating their bodies.
- Environment Awareness & Skills: people have a sense of their surroundings and possess skills for negotiating, manipulating, and navigating within their environment.
- Social Awareness & Skills: people are generally aware of others in their environment and have skills for interacting with them.

We hope to advance the study of emerging interaction styles with a unifying framework that can be used to understand, compare and relate these new interaction styles. The reality-based interaction (RBI) framework characterizes a large subset of seemingly divergent research areas. The framework consists of four themes: naïve physics, body awareness and skills, environment awareness and skills, and social awareness and skills. Based on these themes, we show implications for the design and analysis of new interfaces. Our framework is primarily a descriptive one. Viewing the emerging generation of interfaces through the lens of reality-based interaction provides researchers with explanatory power. It enables researchers to analyze and compare alternative designs, bridge gaps between seemingly unrelated research areas, and apply lessons learned from the development of one interaction style to another. It can also have a generative role by suggesting new directions for research, such as incorporating RBI themes in the design of interfaces for different user populations (e.g. children or expert users) or studying the effects of different degrees of RBI themes in an interface.

A.5 Usability Study - Phase 3 – Usability Questionnaire

This section presents the usability questionnaire we used for usability study.

Usability Study - Post Study System Usability Questionnaire

Participant #____ Date _____

1. Gender M F

2. Domain _____

3. I am quite comfortable using digital technology.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

4. I am quite comfortable using web based application.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

5. I am quite comfortable with use of digital technology/medium.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

6. I was able to efficiently complete given task using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

7. I felt comfortable using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

8. It was easy to learn to use this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

9. I believe I could become productive quickly using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

10. The system gave error messages that clearly told me how to fix problems.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

11. Whenever I made a mistake using the system, I could recover easily and quickly.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

12. The information regarding how to use this system (such as tutorial, on screen messages etc.) provided with this system was clear.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

13. It was easy to locate the information I needed.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

14. The information provided for the system was easy to understand.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

15. The information was effective in helping me complete given task.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

16. The organization of information on the system screen was clear.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

17. The interface of this system was pleasant

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

18. I liked using the interface of this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

19. Overall I am satisfied with this system

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

A.6 Comparative Study - Phase 3 – Stimulus Material

We referred 'embodied interaction: exploring the foundations of a new approach to hci' (Dourish, P., http://www.douri.sh/embodied/embodied99.pdf), 'six views of embodied cognition' (Wilson, W., 2002), 'how bodies matter: theories of embodiment' (Klemmer, S., 2006) papers, and extracted abstracts from these papers in order to create a stimulus material for our comparative study. Following abstracts presents the stimulus material used in the comparative study

Embodied Interaction: Exploring the Foundations of a New Approach to HCI

Embodiment, in a variety of forms, has been a critical component of phenomenological thought throughout the twentieth century. It is to this philosophical approach that we will turn to look for guidance in formulating new foundation for interaction and interactive systems. First, though, we will consider how it is that we came to this point. As with any exploration of the future, we first need a good understanding of the past and the present. What has been presented here is the outline of an embodied approach to HCI. This approach weaves together recent threads in research into interactive systems, and in particular concerns with social and tangible computing. The goal of the project reported here is to place recent developments on a stronger foundation, and to foster recognition of their common orientation towards a set of shared concerns. However, on the occasion of this issue, it seems appropriate in addition to consider what implications this approach holds for the future of interactive system development. When I write with a pen, I become coupled with it in such a way that my

actions can be carried out at the level of words and sentences, not marks on paper. The pen is still critically present, though. An invisible pen would be a hard thing to use. The notion of the invisible interface confuses coupling with visibility. An interesting perspective on the notion of invisible user interfaces, or other interfaces that recede into the background, is raised by recent work that uses the computer interface as a site for creative design. For instance, the "intimate interfaces" presented by Strong and Gaver (1996) are anything but invisible. They are explicitly meant to be engaging. Dunne and Gaver (1997) discuss the role of "artists-designers", and point out that, while the role of the designer in HCI might often be thought of as being to beatify, they see the role of the artist-designer as being to engage and to question. What is notable about their designs is their physicality; their embodiment serves not to render them invisible, but rather to encourage a deeper engagement. Embodied interaction, then, suggests that the future of interaction lies not in the interface "disappearing", but rather in the interface becoming even more visible, or rather, available for a wider range of engagements and interactions. The question is, what form will that heightened visibility take?

Six Views of Embodied Cognition

The paradigm of embodied cognition is progressively asserting itself in the domain of Cognitive Science: the mind is no longer conceived of as a set of logical/abstract functions, but as a biological system rooted in bodily experience and interconnected with bodily action and interaction with other individuals. From this perspective, action and representation are no longer interpreted in terms of the classic

physical–mental state dichotomy, but are closely interconnected. Acting in the world, interacting with objects and individuals in it, representing the world, perceiving it, categorizing it, and understanding its significance are perhaps simply different levels of the same relational link that exists between organisms and the local environments in which they operate, think, and live. Traditionally, the various branches of cognitive science have viewed the mind as an abstract information processor, whose connections to the outside world were of little theoretical importance. Perceptual and motor systems, though reasonable objects of inquiry in their own right, were not considered relevant to understanding "central" cognitive processes. Instead, they were thought to serve merely as peripheral input and output devices. This stance was evident in the early decades of cognitive psychology, when most theories of human thinking dealt in propositional forms of knowledge. During the same time period, artificial intelligence was dominated by computer models of abstract symbol processing. Philosophy of mind, too, made its contribution to this zeitgeist, most notably in Fodor's (1983) modularity hypothesis. According to Fodor, central cognition is not modular, but its connections to the world are.

There is a growing commitment to the idea that the mind must be understood in the context of its relationship to a physical body that interacts with the world. It is argued that we have evolved from creatures whose neural resources were devoted primarily to perceptual and motoric processing, and whose cognitive activity consisted largely of immediate, on-line interaction with the environment. Hence human cognition, rather than being centralized, abstract, and sharply distinct from peripheral input and output

modules, may instead have deep roots in sensorimotor processing. Although this general approach is enjoying increasingly broad support, there is in fact a great deal of diversity in the claims involved and the degree of controversy they attract. If the term-embodied cognition is to retain meaningful use, we need to disentangle and evaluate these diverse claims.

How Bodies Matter: Theories of Embodiment

Our physical bodies play a central role in shaping human experience in the world, understanding of the world, and interactions in the world. This paper draws on theories of embodiment — from psychology, sociology, and philosophy. We introduce aspects of human embodied engagement in the world with the goal of inspiring new interaction design approaches and evaluations that better integrate the physical and computational worlds.

The richness of human knowledge and understanding is far deeper than the set of knowledge we can produce a symbolic account of. As Polanyi puts it, "we know more than we can tell". To elucidate this assertion, consider riding a bicycle: one is simultaneously navigating, balancing, steering, and pedaling; yet it is not possible for bicyclists to articulate all of the nuances of an activity that they successfully perform. Perhaps the most remarkable aspect of this is that riding a bicycle is just one of thousands of activities that our bodies can do. Contrast the richness, subtlety, and coordination of tasks at several levels of concern that bicycling offers with the graphical user interface that we use today. One of the most sweeping — and unintended —

transformations that the desktop computing paradigm has brought about is the extent to which the physical performance of work has homogenized. For certain activities, such as writing this paper, the keyboard interaction paradigm appropriately leverages our bimanual dexterity. But, with a keyboard and mouse interface, the use of our bodies for writing a paper is the same as for editing photographs. And playing music, communicating with friends and family and anything else that one might want computation for.

This paper presents five themes that we believe are particularly salient for designing and evaluating interactive systems. The first, thinking through doing, describes how thought (mind) and action (body) are deeply integrated and how they co-produce learning and reasoning. The second, performance, describes the rich actions our bodies are capable of, and how physical action can be both faster and more nuanced than symbolic cognition. The first two themes primarily address individual corporeality; the next two are primarily concerned with the social affordances. Visibility describes the role of artifacts in collaboration and cooperation. Risk explores how the uncertainty and risk of physical co-presence shapes interpersonal and human-computer interactions. The final theme, thickness of practice, suggests that because the pursuit of digital verisimilitude is more difficult than it might seem, embodied interaction is a more prudent path.

A.7 Comparative Study - Phase 3 – Pre-study Expertise Questionnaire

This section presents the pre study - expertise questionnaire we used for comparative study.

Comparative Study – Pre-Study Expertise Questionnaire

Participant #____ Date _____

Gender M F

Domain _____

- Rate on scale of (lowest) 1 – (highest) 7, how good you are in literature review?
- Rate on scale of (lowest) 1 – (highest) 7, how much do you know about Human Computer Interaction (HCI)?
- Rate on scale of (lowest) 1 – (highest) 7, how often do you do literature review?
- Rate on scale of (lowest) 1 – (highest) 7, how much literature review do you do?

A.8 Comparative Study - Phase 3 – Post-Study Usability Questionnaire

This section presents the post study - usability questionnaire we used for comparative study.

Comparative Study - Post Study System Usability Questionnaire

Participant #____ Date _____

1. Gender M F

2. Domain _____

3. I am quite comfortable using digital technology.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

4. I am quite comfortable using web based application.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

5. I am quite comfortable with use of digital technology/medium.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

6. I was able to efficiently complete given task using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

7. I felt comfortable using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

8. It was easy to learn to use this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

9. I believe I could become productive quickly using this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

10. The system gave error messages that clearly told me how to fix problems.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

11. Whenever I made a mistake using the system, I could recover easily and quickly.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

12. The information regarding how to use this system (such as tutorial, on screen messages etc.) provided with this system was clear.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

13. It was easy to locate the information I needed.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

14. The information provided for the system was easy to understand.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

15. The information was effective in helping me complete given task.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

16. The organization of information on the system screen was clear.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

17. The interface of this system was pleasant

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

18. I liked using the interface of this system.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

19. Overall I am satisfied with this system

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

A.9 Comparative Study - Phase 3 – Post-study Method Questionnaire

This section presents the post study – method/process questionnaire we used for comparative study.

Comparative Study - Post Study System Method Questionnaire

Participant #____ Date _____

1. Gender M F

2. Domain _____

3. It was easy to follow method used in this study.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

4. I was satisfied with the method used in this study.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

5. I was productive while using this method.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

6. I was comfortable using this method.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

7. I think this is an effective method.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

8. I think this is an efficient method.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

9. I was able to do given task clearly using this method.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

A.10 Comparative Study - Phase 3 – Post-Study Report Questionnaire

This section presents the post study - report questionnaire we used for comparative study.

Comparative Study - Post Study System Report Questionnaire

Participant #____ Date _____

1. Gender M F
2. Domain _____
3. I think my report was comprehensive.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

4. I think my report was coherent.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

5. I think my report was rich.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

6. I am satisfied with my report.

(Strongly disagree) 1 2 3 4 5 6 7 (Strongly agree)

Comments: _____

A.11 Comparative Study - Phase 3 – Post-Study Interview

For the semi-structured interview questions, which will be asked are given as follows

- What process did you use for report generation?
- What do you think of this system and the method used in this study?
- Are you satisfied with the report you generated? Why?

A.12 Permissions to use Referenced Images

A.12.1 Permission to use figure (3) - VKB showing Organized Resources

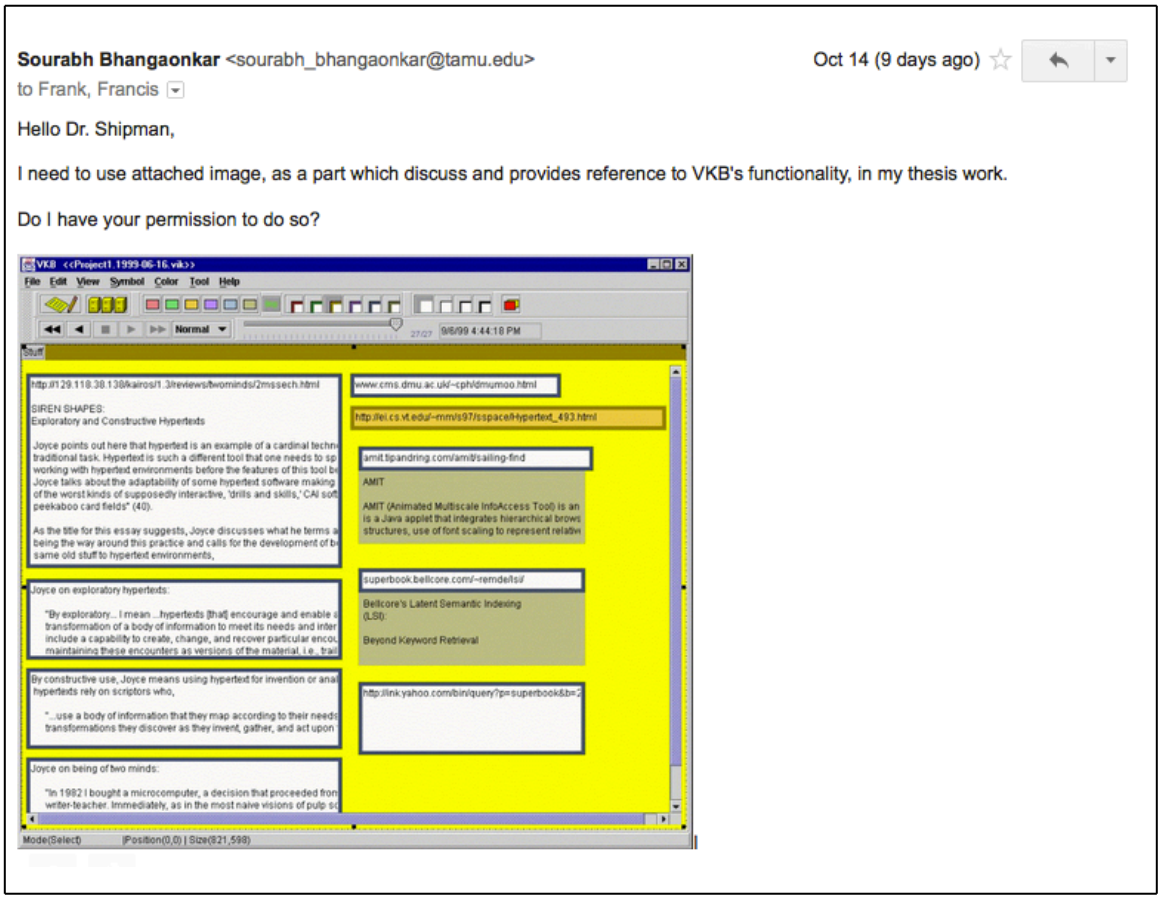


Figure 25 Request to use VKB Image Reference

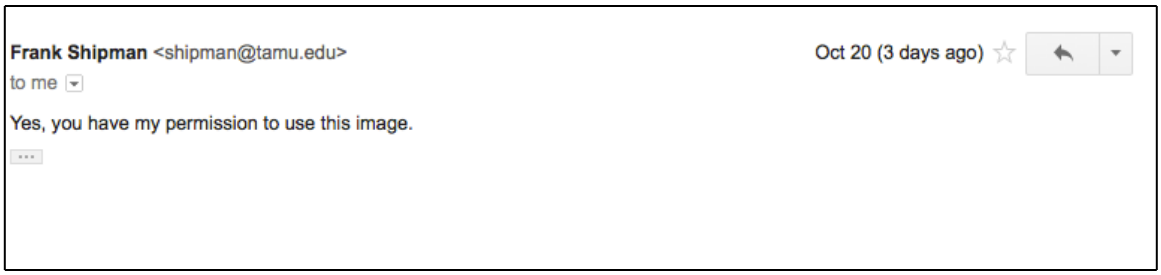


Figure 26 Permission to use VKB Image Reference

A.12.2 Permission to use Figure (4) - Semantic Interaction showing Documents Spatially getting arranged for further Synthesis

Sourabh Bhangaonkar <sourabh_bhangaonkar@tamu.edu> Oct 14 (9 days ago)

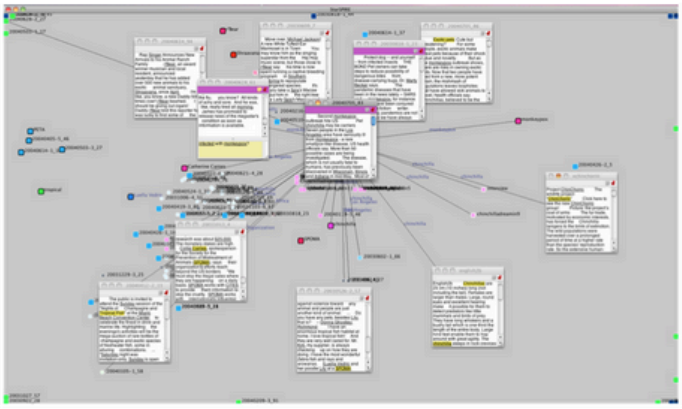
to endert, Sharon

Hello Dr.Endert,

I am a graduate student at Texas A&M University, working with Dr. Chu.

I need to use attached image in my thesis work, to discuss and provides reference to Semantic Interaction system.

Can I get your permission to use this image in my thesis work? Thanks



Sourabh Bhangaonkar

MS Student
Student Research Assistant
Department of Visualization
Texas A&M University
TAMU Embodied Interaction Lab: http://teilab.tamu.edu/index.php?title=TAMU_Embodied_Interaction_Lab_(TEILab)

Figure 27 Request to use Semantic Interaction Image Reference

Alex Endert Oct 15 (8 days ago)

to me, Sharon

Hi Sourish, Sharon-

Yes. You have my permission.

Thanks for asking.

-Alex

--
Alex Endert
Assistant Professor
School of Interactive Computing
Georgia Tech
http://www.cc.gatech.edu/~aendert3
(email) endert@gatech.edu
(phone) (404) 385-4477

Figure 28 Permission to use Semantic Interaction Image Reference

A.12.3 Permission to use Figure (5) - A Student presentation organized using IdeaMache, providing Zoom in and Zoom out Views.

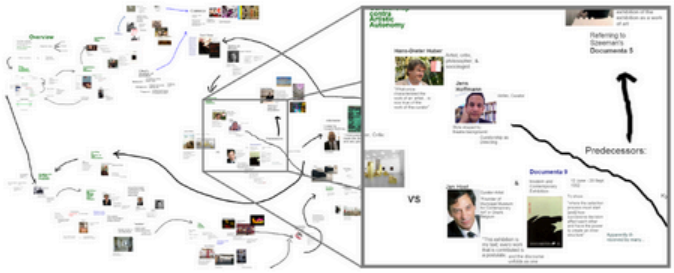
Sourabh Bhangaonkar <sourabh_bhangaonkar@tamu.edu> Oct 14 (9 days ago)

to Andruid, Andruid, Francis

Hello Dr.Kerne,

I need to use attached image, as a part where it discuss and provides reference to IdeaMache's functionality, in my thesis work.

Do I have your permission to use this image in my thesis work? Thanks



Sourabh Bhangaonkar

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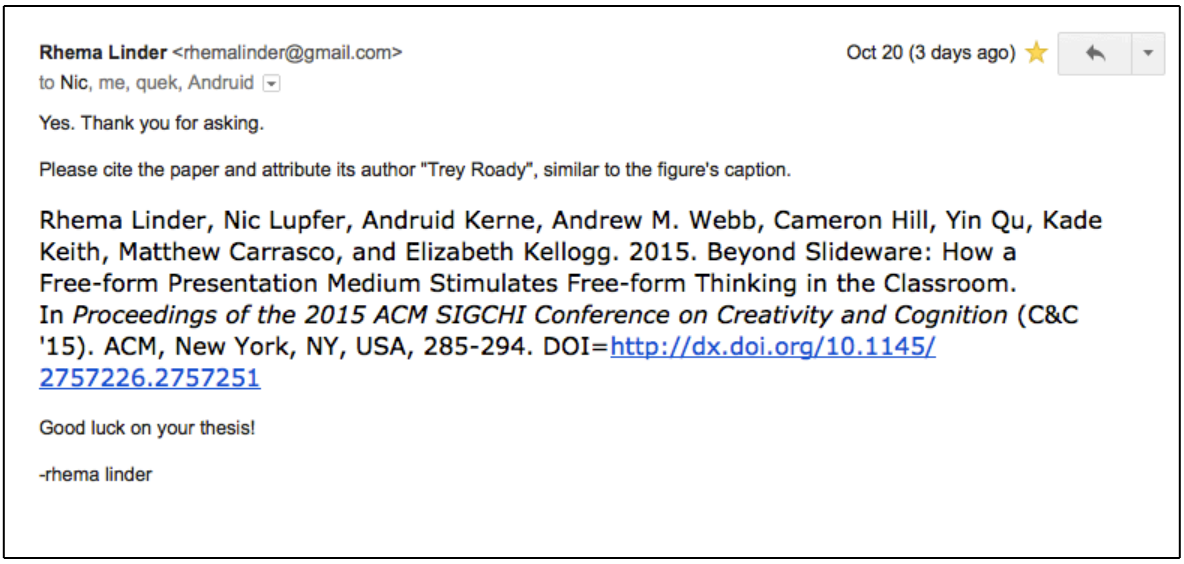
Department of Visualization
Texas A&M University
TAMU Embodied Interaction Lab: http://teilab.tamu.edu/index.php?title=TAMU_Embodied_Interaction_Lab_(TEILab)

Figure 29 Request to use IdeaMache Image Reference



Rhema Linder <rhemalinder@gmail.com> Oct 20 (3 days ago)

to Nic, me, quek, Andruid

Yes. Thank you for asking.

Please cite the paper and attribute its author "Trey Roady", similar to the figure's caption.

Rhema Linder, Nic Lupfer, Andruid Kerne, Andrew M. Webb, Cameron Hill, Yin Qu, Kade Keith, Matthew Carrasco, and Elizabeth Kellogg. 2015. Beyond Slideware: How a Free-form Presentation Medium Stimulates Free-form Thinking in the Classroom. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition* (C&C '15). ACM, New York, NY, USA, 285-294. DOI=http://dx.doi.org/10.1145/2757226.2757251

Good luck on your thesis!

-rhema linder

Figure 30 Permission to use Idea Mache Image Reference